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ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated. Names of authors of papers, etc., are printed in *italics*.

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ELECTRIC RAILWAY BRIDGES.

BY WILBUR J. WATSON, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, January 13, 1903.*]

THE interurban electric railway, which has become such an important factor in our modern system of transportation, is a development from urban methods of travel. The city street car lines were extended, first, into the suburban districts, and then still further to the tributary towns and villages, and now lines that connect cities a hundred miles or more apart are in operation.

The earlier lines and many of those now being built follow the highway, and use the highway bridges, reinforcing them where necessary, and in many cases, rebuilding the entire highway bridge.

The tendency at present, however, seems to be in the direction of separation from the highway, building the electric line alongside the road on private property purchased by the railway company, or across the fields wherever the exigencies of the route demand it.

Many long lines are being constructed at present which follow the highway only a very small part of their lengths.

The early city lines used cars of small weight and capacity as compared with those now in use, and the ordinary city street bridges, designed for vehicular traffic, were of ample strength to carry them; but the weights and capacities of the cars used have rapidly increased, more so in the case of the interurban companies than in that of the urban companies, the former using greater speed and requiring motors of greater capacity and weight, and larger and heavier cars. Only a few years ago, cars weighing 20 tons, total load, distributed on eight wheels, represented the heaviest in use. To-day, cars 46 feet long, weighing, when loaded, about 40 tons, distributed on eight wheels, are in common use on interurban lines,

*Manuscript received January 29, 1903.—Secretary, Ass'n of Eng. Socs.

and as nearly all of these cars pass through the cities over the urban street car lines, it is necessary to examine into the city bridges to carry them, as well as the county bridges which are used by the railway company.

But this does not seem to be the limit of loading for many of these lines, as very many of them carry freight traffic at present and many more will in the future. Some of them are now carrying coal and in some regions the railway officials expect the coal traffic to be quite an item in their operation; in fact, there seems to be a tendency, in many cases, to approach steam railway conditions of loading.

When the railway line left the highway, it became necessary for the company to erect bridges of its own, and many of them, failing to profit by the expensive experience of the steam railroads, have built these bridges for present needs only, making no provision whatever for future increase in loading, or designing them for passenger and express traffic only, when it is quite probable that, in the near future, it may be desired to haul heavy freight loads over the line.

What is the probable maximum loading which a given bridge will be required to carry, not just at the present time, but within a length of time representing a reasonable life for the structure?

This is a difficult question to answer in most cases, and yet it is essential that it should be answered in order to properly design the structures for any given line, and it is a question that should be answered by the railway officials, who are in a position to know what sort of traffic they may expect to run over their road in the future.

The writer has given this question of loading considerable attention, and proposes that one of the loads given in the table following, taken from the specifications of the Osborn Engineering Company for Electric Railway Bridges, should be adopted.

These loads range all the way from a train of 40-ton passenger cars, designed for a road devoted exclusively to passenger and express traffic, to a loading, consisting of a train of 50-ton capacity coal cars for a load expecting to carry a heavy coal traffic.

Another point that should be borne in mind is the possible use of electric locomotives, which may have concentrations approaching very closely those of the heaviest coal cars.

Before discussing these loadings further, let us see what is the effect of some of the heavy cars now being operated upon existing bridges.

The writer has examined and reported upon very many such structures in the last few years, and while, in the majority of cases, these bridges have been found to be strong enough to carry the loads which were being run over them, or it was possible to make them so with slight changes or repairs, he has found many cases where bridges have been seriously overloaded.

The most common point of weakness in a bridge designed for highway traffic and later used for electric railway traffic is in the floor system and its connections, the greater concentrations of the live load in the case of the electric car over the concentrations of the load used in proportioning highway bridges being responsible for this.

In order to illustrate the effect of these street car loads upon some highway bridges, we will take eight bridges examined by the writer during 1902. All of these eight structures were figured for loadings actually being run over them or proposed to be used in the immediate future.

1. Through highway span, 108 feet long, 20 feet roadway and two 5 feet walks. Iron Fink trusses; railway track on one side of the roadway next to the trusses; live load, one 25-ton double truck motor and 60 pounds per square foot on sidewalks and on that portion of the roadway not occupied by the street railway tracks.

This loading caused, in the main members of the trusses, a unit stress amounting to 25,000 pounds per square inch, not including the effect of impact. The elastic limit of the material was probably about 27,000 pounds per square inch.

2. Highway bridge, 195 feet long, 20 feet roadway, no sidewalk, Pratt trusses; one track at one side of the roadway; material, iron. Live load consists of two double truck cars, weighing 36 tons each, including passengers, and 60 pounds per square foot on the unoccupied portion of the roadway.

This loading gave, in the floor system, a unit stress of 22,000 pounds per square inch and, in the main truss members, 27,800 pounds per square inch. Owing to the greater impact on the floor, the actual stress in the floor system was probably in excess of that in the main members. The elastic limit of the material was probably about 27,000 pounds per square inch.

3. Highway bridge, built 1886, 123 feet span, 15 feet roadway; material, iron. Figured for two 36-ton double truck motors, including passengers, and no other load on the bridge; unit stress 21,000 pounds per square inch in the floor system and 11,000 pounds per square inch in the main truss members.

4. Highway bridge, built in 1900, 233 feet span, 20 feet clear roadway, no sidewalks; material, steel. Figured for same live load as preceding bridge, and 60 pounds per square foot on that portion of the roadway not occupied by the street railway tracks. Unit stress 16,400 pounds per square inch in the floor system; unit stresses in the truss members from 18,000 to 27,000 pounds per square inch, excepting one member, a counter rod, which was stressed 41,000 pounds per square inch. A comparison of these two bridges, one built in 1886 of iron and the other built in 1900 of steel, is edifying; the older bridge being very much stronger than the newer.

5. One span, 158 feet long, 15 feet roadway, through Pratt truss built in 1881; the same load as preceding bridges; maximum unit stress in the floor, 25,000 pounds per square inch; in the trusses 14,500 pounds per square inch.

In the case of this bridge, the members of the floor system, which are so highly stressed, were additions made when the electric railway was built. They are not nearly so strong as the old portions of the structure.

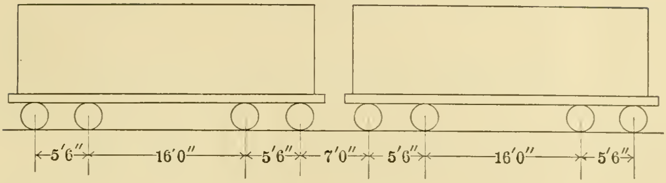
6. Highway bridge, 233 feet long, 20 feet roadway and two sidewalks. Through Whipple trusses. Figured for a live load consisting of one 20-ton car and 60 pounds per square foot on that portion of the roadway not occupied by the street railway track.

This loading caused unit stresses as follows: 37,500 pounds per square inch in floor system; 20,400 pounds in the truss members. It is difficult to say what kept this structure standing, as the elastic limit of the material could not have been much in excess of 27,000 pounds per square inch, and the safe capacity of this bridge was not much in excess of 30 pounds per square foot uniform load, yet cars of very nearly this weight were actually running over the bridge, though operated with great care.

7. Highway bridge, 202 feet long, 20 feet roadway; two 6 feet sidewalks; Whipple truss.

This was a city bridge, and carried one street car track in the center of the roadway. The live load assumed was two 40-ton cars and 60 pounds per square foot on the unoccupied portion of the roadway and sidewalks. The maximum unit stress in the truss members was about 18,000 pounds per square inch, and in the floor system about 25,000 pounds per square inch.

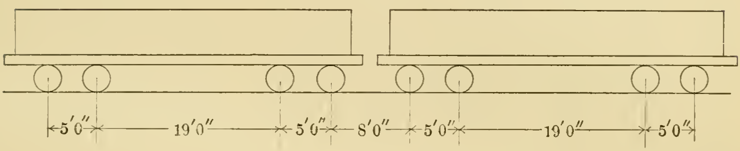
8. This is a highway bridge, 203 feet span, 18 feet roadway and two 6 feet sidewalks, and subject to heavy traffic. The live load assumed consisted of one 15-ton street car on a 7-foot wheel base and 30 pounds per square foot on the unoccupied portion of



LIVE LOAD "A."

Train of 74-Ton Coal Cars.

Weight of car	= 38,000 lbs.
Rated capacity	= 100,000 lbs.
10% overload	= 10,000 lbs.
Total load	= 148,000 lbs.
Axle load	= 37,000 lbs.



LIVE LOAD "B."

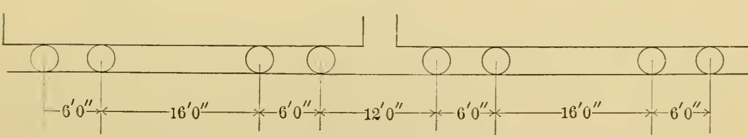
Train of 62-Ton Coal Cars.

Weight of car	= 36,000 lbs.
Rated capacity	= 80,000 lbs.
10% overload	= 8,000 lbs.
Total load	= 124,000 lbs.
Axle load	= 31,000 lbs.

LIVE LOAD "C."

Train of 46-Ton Flat Cars. Same wheel spacing as for 62-Ton Coal Cars.

Weight of car	= 26,000 lbs.
Rated capacity	= 60,000 lbs.
10% overload	= 6,000 lbs.
Total load	= 92,000 lbs.
Axle load	= 23,000 lbs.



LIVE LOAD "D."

Train of 40-Ton Motors.

Axle load	= 20,000 lbs.

NOTE.—Live load "A" should be used for roads designed for heavy coal traffic, etc. Live load "B" should be used for roads designed to carry occasional coal cars. Live load "C" should be used for roads designed to carry ordinary freight traffic, but not cars of over 60,000 lbs. capacity; this excludes coal traffic. Live load "D" should be used for roads designed to carry passenger and express traffic only.

roadway and sidewalks, or one motor as above described and one 5-ton wagon on the bridge, whichever would give the greater stress. The stresses found were 23,000 pounds per square inch in the floor system and 27,000 in the main truss members. The elastic limit of the material was about 27,000 pounds. In this case also, the loads assumed were those actually being run over the bridge.

Taking up again the design of new structures for electric railways, the writer has made a comparison of six specifications for use in designing electric railway bridges, and has applied them to the design of a 135-foot through pin-connected Pratt truss for a single-track road. This comparison is made in order to show the wide variation in specifications in use, the relative weight of each structure and the relative efficiencies when loaded with a live load consisting of a train of coal cars of 80,000 pounds capacity.

The first specification is that of the Osborn Engineering Company, using a live load consisting of a train of coal cars as stated above. The second is the specification and loading recommended by the Massachusetts Railroad Commission. The third is the Osborn Engineering Company's specifications and loading for heavy steam railroad bridges, and the other three are specifications in use by three large traction companies. The last column gives the moments in foot-pounds produced on a stringer 22 feet 6 inches long by these respective loads, and does not take into account the question of impact. This column shows the desirability of using some other loading than the ordinary passenger cars on roads which may be used for any other character of loading. The much larger moments produced by the coal-car loading are due mostly to the closer spacing of the wheels when these cars are run in trains of two or more.

IMPACT.

The matter of impact; that is, the increase in live load stresses produced in a structure by the pounding of the wheels, the swaying of the car, etc., is of as great importance in the design of electric railway structures as in the design of steam railway structures. In the case of bridges located in a sag of the grade, as many such bridges are, on electric lines, the impact is still further increased by the momentum of the car.

In many specifications this matter of impact is not properly provided for. In the practice of the Osborn Engineering Company the impact is taken care of by adding to the live load stress a percentage determined by the formula

$$I = \frac{L(L)}{L + D}$$

in which

I = the impact to be added to the live load stress,
L = the live load stress,
D = the dead load stress.

This formula is correct in theory, and has been found to satisfy the requirements of practice very well.

FACTOR OF SAFETY.

The term "Factor of Safety" of a bridge is misleading, and is absolutely meaningless unless the effect of impact has been fully taken care of in calculating the live load stress.

As ordinarily used, it means the ratio of the ultimate strength of the material, when tested to destruction, to the actual stresses in the bridge caused by the dead and live loads, not considering impact.

In the first place, it is not possible to strain steel repeatedly above its elastic limit without causing failure, and therefore the factor of safety should be based upon the elastic limit and not upon the ultimate strength of the material.

In the second place, it is necessary to take the effect of impact into full consideration in order to determine the actual stress in each member of the bridge. Complying with these two conditions, the bridges designed under the specifications which follow have a factor of safety of two based upon the elastic limit of the material and taking the effect of impact fully into account. The writer believes that these bridges are much stronger and better proportioned throughout than bridges designed for this same loading with a specified factor of safety of four, as ordinarily understood, or perhaps, misunderstood.

A bridge should be built like the Deacon's One Hoss Shay, so that when loaded to destruction every member should fail at the same time. In writing these specifications, we have endeavored to approach as nearly as possible this ideal.

The clauses referring to clearance, quality of material and grade of workmanship and the general conditions governing contract work all follow very closely the standard specifications for steam railway bridges. The following review gives the most salient features of these specifications for electric railway bridges.

Section I gives the requirements for clearance, which are identical with those now adopted by the leading steam roads, 21 feet vertical and 15 feet lateral, clear room.

Section II, drawings, requires all drawings to be of a uniform size, 24 inches by 36 inches, and specifies what the drawings must show, etc.

Section III, floor, gives sizes of ties required for different spacing of stringers, and spacing of same, ribbons, and manner of securing same.

Section IV, loads. The table of loadings is given in the appendix, and this section provides for the impact by the use of the formula given above. The effects of centrifugal, longitudinal and wind forces are also covered by this section.

Section V, unit stress. A unit stress of 17,000 pounds per square inch is used for soft steel members in tension, this allowed unit stress being increased to 19,000 for medium steel, the corresponding stresses used for steam railway bridges being 15,000 and 17,000 pounds per square inch, respectively.

This increase in the allowed unit stresses over those used for steam railway bridges may seem to be somewhat inconsistent with what has been said in regard to the design of these bridges, but in proportioning bridges for steam railway use a lower unit stress is used in order to leave some room for increase in the live load over the loads now actually running, which approach very closely to the typical loads used in proportioning the structure, while in designing electric railway bridges we have assumed a loading which we think fully covers the probable, if not the possible increase in loads which may reasonably be expected to take place. Furthermore, the loads are not applied in such rapid succession as in the case of steam railway bridges.

Therefore we are warranted in using a higher unit stress.

For compression members, the above unit stresses are decreased by Gordon's formula for columns.

It should be borne in mind that the effects of impact are fully taken care of in the total live load stress, and not in the unit stress, as is done in many of the older specifications.

It might be well to state here that impact formulæ have been adopted by many of the leading bridge engineers, among them Messrs. J. A. L. Waddell of Kansas city, C. C. Schneider of the American Bridge Company and J. E. Greiner of the B. & O. Company, all of whom, however, use an empirical formula, based upon experiments. The writer has compared the empirical formula used by these eminent engineers with the rational one used by him, and finds that they give results very nearly identical. The rational formula results about 10 per cent. higher than the empirical for short spans of about 10, results identical with the

empirical formula for spans of about 50 feet to 100 feet and somewhat greater for spans of over 100 feet the excess being about 10 per cent. for spans of 150 feet. This comparison was made for heavy steam road loading, but the ratios would not be greatly changed for electric railway practice.

This impact formula was first brought to the writer's attention by the paper read by Mr. J. W. Schaub, C.E., before the Western Society of Engineers, October 3, 1900, on proposed specifications for steel railway bridges, and is there attributed to Mr. H. S. Prichard, engineer for the New Jersey Steel and Iron Company, who is said to have first proposed its use in 1895.

The writer designates this formula the "Rational" impact formula.

One of the greatest advantages of the impact formula is the ease with which it is possible to carry the impact into all details and connections of the structure, which are of quite as much importance as the main members.

Members subject to alternate strains of tension and compression in quick succession are given a section equal to that required to resist the sum of these stresses.

Section VI deals with general details, and covers the determination of net sections, maximum and minimum rivet spaces, least thickness of metal, limiting values of ratios of length of columns to their least radius of gyration, etc.

Section VII deals with I beam spans; Section VIII with plate girder spans; Section IX with stringers and floorbeams, and Section X with trusses and towers.

All the requirements of these sections follow well-established practice in railway bridge design.

Section XI covers riveted work, requirements of punching and drilling, reaming, etc. In the use of soft steel all holes in tension members less than $\frac{3}{4}$ inch thick are to be sub-punched and reamed. In metal $\frac{3}{4}$ inch and over they are to be drilled from the solid.

All holes in compression members may be punched full size up to $\frac{3}{4}$ inch, and for thicknesses of $\frac{3}{4}$ inch and over must be drilled from the solid.

In the case of medium steel, full sized punching of rivet holes is not allowed in main members.

Section XII covers requirements as to quality of material, which conform closely to those recommended by Committee No. 1 American Section of the International Association for Testing Materials, and to the specifications of the American Association of Steel Manufacturers.

In regard to paint, a very important item, the practice of the Osborn Engineering Company is to give the material one coat of graphite or carbon primer at the shop and two coats in the field, the quality and color of the latter being specified by the engineer for each individual case. Inaccessible surfaces are given two coats of red lead and oil.

Section XIII deals with workmanship; Section XIV with questions relating to inspection and tests, and Section XV with erection.

A dispute frequently takes place between the contractor for substructure and the contractor for superstructure as to which shall place the anchor bolts. It is the general practice of the Osborn Engineering Company to require all anchor bolts to be set by the substructure contractor, and furnished by the superstructure contractor.

Section XVI gives the requirements for name plate.

Section XVII covers general conditions, in regard to changes, abandonment of work, subletting, claims, estimates and payments, etc.

In the appendix are given the clearance diagram, the loadings and the rivet code.

COMPARISON OF SOME ELECTRIC RAILWAY BRIDGE SPECIFICATIONS.

Based upon the design of a 135-foot through, Pratt truss, single track bridge.

SPECIFICATIONS.	LOADING.	Comparative Weights of Structures.	Strength Based on "*a*" Loading.	Actual Weight on Bridge Allowed by Each Specification.	Live Load Bending Moments on Stringers. Span = 22′ 6″. Impact not Considered.
Osborn Engineering Co. Specification "*a*"	Train of 62-ton coal cars	100%	100%	217 tons	158,500 lbs.
Specification "*b*"	1-40 ton motor, 5′ wheel, base 25′ *c* to *c* trucks + 1413 lbs. per ft.	65%	35%	107 "	88,750 "
Specification "*c*" for heavy steam railways	2-177½ ton engines followed by 5000 lbs. per lineal ft.	160%	190%	420 "	320,000 "
Specification "*d*"	1-40 ton motor and 125-ton trailer or 2000 lbs. per ft.	60%	42%	135 "	84,500 "
*Specification "*e*"	Train of 75-ton electric cars	82%	70%	300 "	187,500 "
Specification "*f*"	1-40 ton electric locomotive on 7′ wheel base + 2500 lbs. per ft.	96%	70%	170 "	160,000 "

* Specification "*e*" uses a very high unit stress.
NOTE.—Column giving relative strength is correct for loading of 62-ton coal cars only.

ELECTRIC SHOP DRIVE.

Discussion before the Engineers' Club of St. Louis, January 7, 1903.*

W. A. Layman.—It is the purpose of this brief introductory paper to outline roughly the various methods of electric shop drive, leaving the discussion of their relative merits to the Club.

When electric shop drive was first advocated, the main advantage claimed was a large increase in efficiency over the old methods of belt and rope transmission. Of late, however, another, and, in my opinion, a greater advantage appears in the opportunity for increased shop output, resulting from the ability to operate the individual electrically driven tool continuously at its maximum output. Shop managers are to-day keenly alive to the fact that, by means of electric drive, the output of individual tools may be easily doubled and sometimes trebled over that possible with the ordinary belt drive.

It is fair to say the discussion of electric shop drive is no longer one of merit, as compared with the old methods of transmission, but rather one of relative merit of the various electrical methods proposed.

It is claimed on the score of efficiency alone that the best electric methods of to-day show an efficiency of 70 per cent., as compared with 20 and 25 per cent. by the old systems. Adding to this the possibility of double or treble output, the greater advantage of electric shop drive is such as to mean its rapid adoption of all branches of manufacturing.

Electric drive may be roughly classified under two headings—group and individual tool system. The former may be termed a compromise between the old and the best of the new.

In its best adaptations, group drive is so arranged as to have various classes of machine tools subdivided into groups of from 6 to 10 tools, each group being operated by a single motor. By such arrangement, the efficiency of shop drive is increased, roughly speaking, from 25 to 50 per cent. There is a further advantage over belt transmission from a single engine in ability to operate any single group of tools entirely independent of the balance of the equipment. Independence of departments is fully secured by this means. A given group of tools may be completely shut down when not required, and a large loss of energy otherwise unavoidable cut off. This form of drive also permits of operation of any particular group of tools at night, with the main power plant shut down, providing auxiliary central station connection is possible.

*Manuscript received February 5, 1903.—Secretary, Ass'n of Eng. Socs.

The factory of the Wagner Electric Manufacturing Company, of this city, is one of a number of local examples of group electric drive. By means of reserve connection with outside central station service it is possible to run any special group of tools overtime, or all night, without operating the company's isolated generating plant.

Engineers agree, however, that the individual motor system is the ideal one where variable speed service of tools is necessary or desirable. In the group system variable speed is impossible, and the individual tools must be regulated for speed variation through inherent gear or cone adjustment.

Both group and individual drive systems may be arranged for either direct or alternating current motors. For all constant speed service the alternating current motor stands on equal footing with the direct current motor. In fact, by reason of its greater flexibility and inexpensive maintenance, the alternating current motor for such work has a material advantage. The disadvantage of the alternating current motor appears for all service requiring frequent starting and stopping and wide speed variation. No entirely satisfactory system has yet been evolved by which speed variation comparable to that possible with the direct current motor can be secured.

The ideal alternating drive would be one having constant speed alternating current motor, equipped with auxiliary mechanical device, where necessary, by which wide range of speed variation could be secured smoothly and simply. Mechanical engineers are working on this problem, and such a system may come. I have seen one striking example of it in the shops of the Lodge & Shipley Machine Tool Company, at Cincinnati. The company has evolved a system of intermediate gears neatly enclosed in dust-proof case, which they call a "speed variator." The driving shaft of this speed variator is direct coupled or belted to the constant speed motor, and by means of a shifting handle, much like the ordinary belt shifter, the gear combinations of the variator are successively changed without stopping the tool, and with no greater effort on the part of the attendant than would be called upon for manipulating the regulator handle of a direct current motor controller. This device has not come into general use, although a large portion of the machine tools in the Lodge & Shipley factory are operated through it, with results said to be reasonably satisfactory to that company.

With alternating current motor drive shop lighting from the same mains feeding the motors is possible and convenient, while

with the prevailing methods for variable speed direct current motor drive the shop lighting system is practically entirely independent of the motor service system.

The individual drive system may be generally classified under three headings:

Rheostatic control systems.

Multi-voltage control.

Special systems for special tools.

In the rheostatic control system the motor is of the well-known shunt type, supplied from a constant potential system of distribution. Speed variation above the normal speed of the motor is secured by the introduction of resistance into the motor shunt field circuit; speed variation below normal is secured by the introduction of resistance into the armature circuit. This is illustrated in diagrammatic form in Fig. 1.

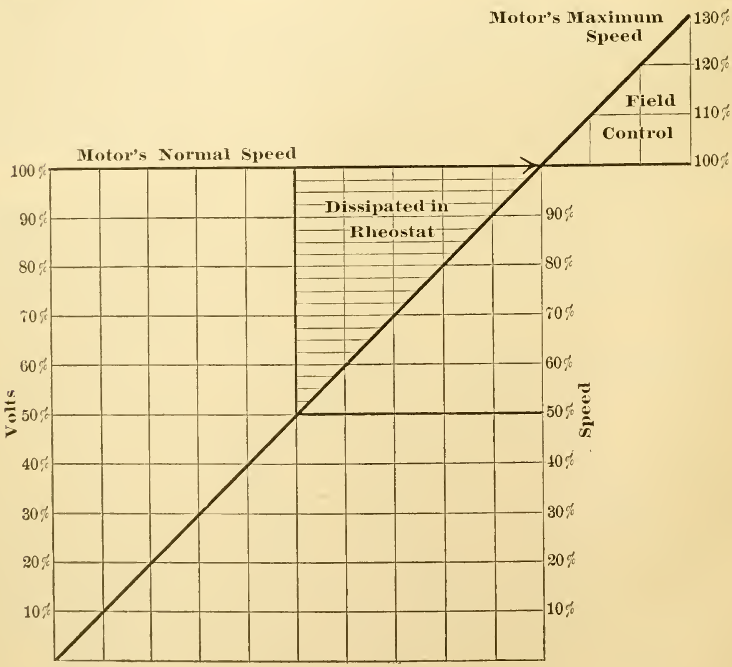


FIG. 1. RHEOSTATIC CONTROL.

The disadvantages of the system are its inefficiency when armature resistance is made use of for speed reduction, and variation of speed on a given armature resistance with variation of load. To overcome both disadvantages, motors have been designed capable

of very wide variation in speed by variation of field resistance. A well-known motor designer stated in a recent discussion before the American Institute of Electrical Engineers that he had designed and built a motor capable of speed variation of one to three (simultaneous load variation not stated) on variation of field resistance alone. In the same discussion an equally well-known motor designer claimed the normal motor was not capable of over 30 per cent. increase in speed, under full load, by field resistance variation.

I think general practice is to confine speed variation by weakening shunt field to 30 per cent., and any motor capable of greater variation can hardly be termed a standard motor. The limit of such variation is determined by commutator sparking. A motor

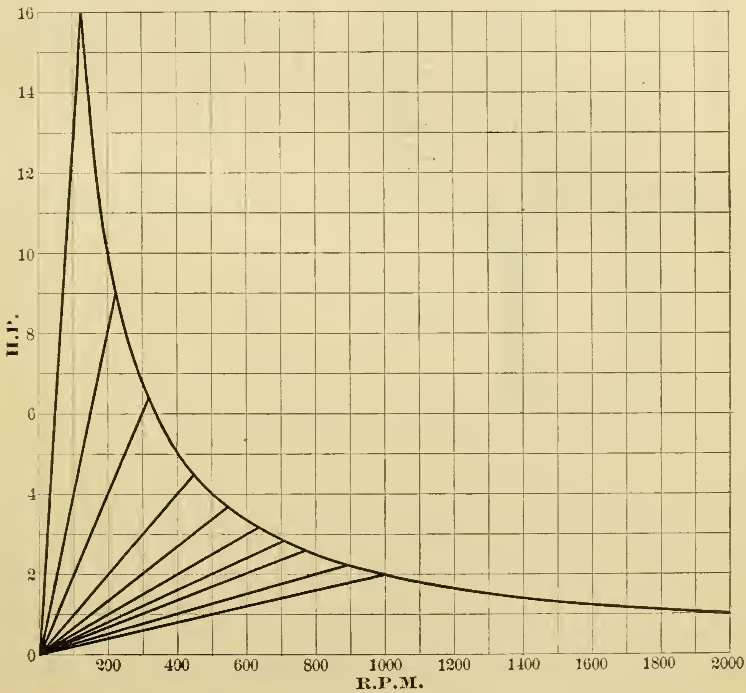


FIG. 2. CURVE A. VARIATION OF SHUNT MOTOR CAPACITY WITH CHANGE OF SPEED SECURED BY VARIATION OF SHUNT RESISTANCE.

of given capacity may be operated, of course, at much reduced capacity for speed variation of 10 to 1. The reduction of capacity, with increase of speed, in this case, is illustrated in curve "A" of Fig. 2. This curve fairly represents the variation in one of the best-known makes of direct current motors. For example, a 10

horse-power motor, operating normally at a speed of 200, will have an output of 1 horse power only at a speed of 2000, speed variation being secured entirely by weakening of the shunt field.

MULTIPLE VOLTAGE SYSTEM.

There are several of these systems. The Westinghouse and General Electric Companies advocate a three-wire system, as illustrated in Fig. 3. Their usual direct current generator is provided

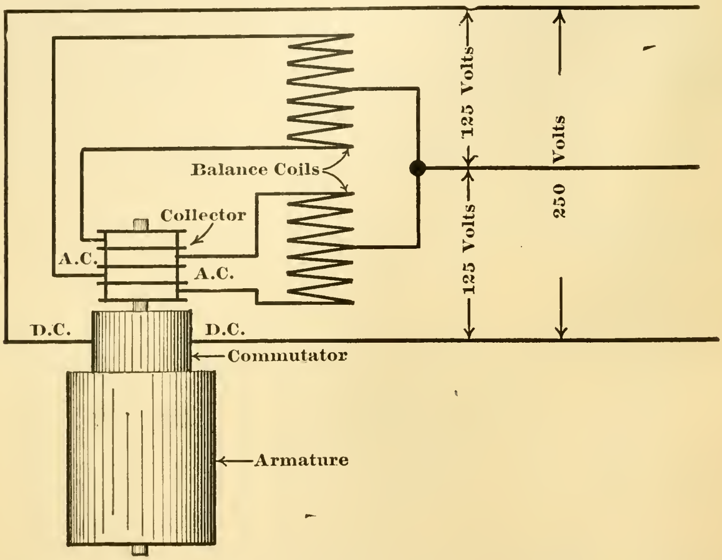


FIG. 3. WESTINGHOUSE THREE-WIRE SYSTEM FOR VARIABLE SPEED CONTROL.

with a set of collector rings, these collector rings being connected to the armature winding in such a way as to establish an exact two-phase relation between the potentials of the two pairs of collector rings. By means of choking coils, connected as shown, the neutral wire of the three-wire system is exactly and constantly maintained, irrespective of load, at zero potential relative to the outside wires.

In connection with this three-wire system, the individual tool is equipped with a standard 250-volt shunt motor, and speed variation is secured in two ways: First, by running the armature either on 250 volts (normal speed condition), or by running it on 125 volts (half normal speed condition). For [illegible] speed desired between normal and half normal, shunt field resistance is introduced. If I understand the system correctly, the shunt motor is

capable of 100 per cent. speed variation by variation of shunt resistance when the armature is on half voltage (and correspondingly at half load). If speed above normal full speed is required, shunt resistance is again introduced.

The Bullock Electric Manufacturing Company advocates a system as illustrated in Fig. 4. A generator, standard in every

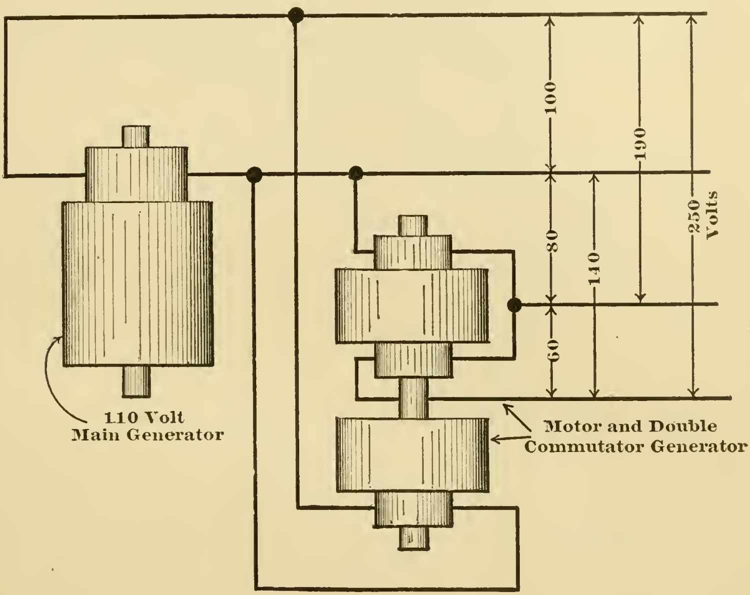


FIG. 4. BULLOCK ELECTRIC MFG. CO.'S MULTIPLE VOLTAGE SYSTEM.

respect, is supplemented by a small motor-generator set, the design of which is such that a four-wire system of distribution is established, providing for six different voltages upon which the motor armature may be operated without the use of armature resistance. The form of motor used is the standard shunt wound type. Without the use of field resistance, six speeds may be secured, corresponding in ratio to the ratio of the voltages supplied by the four-wire distribution system. By means of shunt resistance any speed intermediate to that possible with the several armature voltages may be secured. The motor generator set is so proportioned as to take care of the unbalanced load. This system is also adaptable to three-wire distribution, where less speed variation is required, and in the e[illegible] three-wire distribution an increased amount of field regulation [illegible] introduced. This three-wire distribution differs from the Westinghouse and General Electric system in that

the voltages on the two sides of the intermediate wire differ, thus giving three distinct pressures instead of two. The Bullock system represents the multiple voltage idea carried to its fullest development, and is the extreme of present commercial systems, from the ordinary rheostatic control system. The difference between these systems, from the standpoint of efficiency, is illustrated in Fig. 5 as plotted from the test results on a 25 horse-power motor.

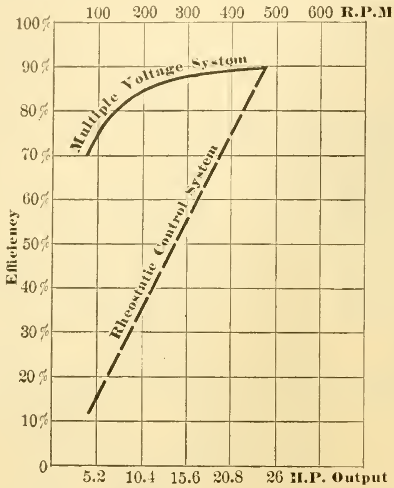


Fig. 5. Efficiency Curves. Multiple Voltage and Rheostatic Control Systems.

I am informed that a system somewhat similar to this is being advocated by the Crocker-Wheeler Company, although I am not prepared to discuss it in detail.

Another form of variable speed equipment is advocated by the C. & C. Company, of New York City. In this case the motor is special, being provided with two entirely independent armature windings. On normal speed operation the two armature windings are connected in parallel, the field winding being in shunt. For half speed the two windings are connected in series; intermediate and excess speeds are secured by a combination of armature and field resistances.

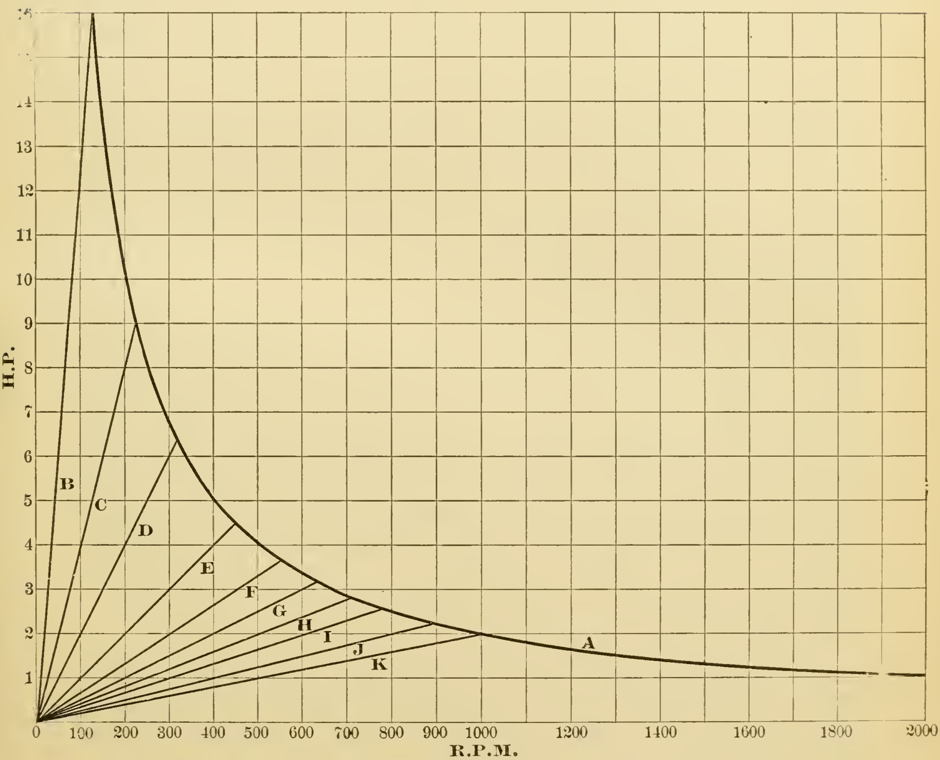
For some kinds of service the storage battery has been introduced with good results, various pressures being applied to the motor armature, from the battery according to the speed required. The objection to the storage battery system is its large first cost.

For printing-press work several special systems have been introduced, the purpose of which is to afford a wide variation of

operating speed. I will not attempt to go into a description of these systems, as they are not intended for general shop service in any sense of the word.

In accordance with the Secretary's instructions, I now leave the discussion of relative merits of systems, etc., to those who follow me on the program.

W. COOPER.—The prime condition to be fulfilled in operating machine-shop tools is to keep the cutting speed at the maximum at all times. This maximum speed is limited, of course, by the



quality of the cutting tool, the kind of material being cut and whether or not any extraneous means are employed to keep the tool from heating.

Nearly all ordinary machine-shop work may be classified under two heads—machining of cylindrical surfaces and plain surfaces.

In considering the first class of operations, the piece being operated upon is usually rotated, and, as a very small proportion of this work has but one diameter on each piece, there must, of

necessity, be provided some way of changing the speed of rotation in order to keep the cutting speed at the maximum. This condition is arrived at in ordinary machine-shop practice on this class of work by using certain arrangements of change gears and by belts on so-called cone pulleys. While it is entirely possible to get a change in this manner of 10 per cent. per step, the complication resulting from the mass of gears and multiplication of steps on the cone pulleys would not be permissible, to say nothing of the time lost in making the changes. As the result of years of practice, this system has developed into an arrangement where the changes are approximately 50 per cent. apart; that is to say, that each increment of increase would be 50 per cent., often being as much as 100 per cent. It is obvious that such an arrangement must be very wasteful of time where the diameter of the piece to be machined is slightly in excess of the nearest combination which would give the maximum cutting speed. The machine, therefore, must be run at slightly more than one-half or two-thirds of the maximum permissible cutting speed, consuming, consequently, nearly 50 to 100 per cent. more time for a given operation than would otherwise be required.

Mr. F. O. Blackwell, of the General Electric Company, in a paper read before the American Institute of Electrical Engineers, said: "The reduction effected by different sets of back gears on machine tools will be found to vary from 4 to 1 to 6 to 1. All tools can be arranged with 4 to 1 changes between back gears without any difficulty. In many cases a single back gear is sufficient for a tool. By putting a magnetic clutch on this back gear and making the electrical connections in the controller, it is possible to get a 6 to 1 variation electrically and without increasing the cost of the motor more than would be required for a 4 to 1 variation."

This is quite different from a statement made by Mr. Chas. Day in a discussion which followed the reading of Mr. Blackwell's paper. He said: "When attaching motors to old tools, such as lathes and drill presses, we must, as far as possible, adapt our speed range to the present gear ratios, in some cases by introducing additional gears, and in others without change to the machine. We have found that the gear ratios vary from 3 to 1 up to 15 to 1, depending on the size and character of the machine."

From the above we see that there is some difference in opinion as regards the range of the back gears of ordinary machine tools. As a matter of fact, the back gear ratio of ordinary machine tools varies from 3 to 1 up to 15 to 1, as stated by Mr. Day. There is

also another fact which has not been touched upon, and that is that the range of speeds given by the cones on a great many machine tools are not consistent with the ratio of the back gearing. That is to say, it is frequently found that the difference between the lowest speed with the back gears out and the highest speed with the back gears in is very much greater than the difference between two cone speeds. Some machines have as much as 3 to 1 variation in speeds between these two conditions. The writer has in mind a case of a comparatively small-sized boring mill made by a prominent manufacturer, in which the back gear ratio was 12½ to 1. In this particular case the difference between the lowest speed with the back gears out and the highest speed with the back gears in was a great deal more than the difference in cone speeds. However, in this case, if we were to allow that the best possible arrangement had been made, the average difference between speeds throughout the entire range of the machine would be about 1.9 to 1, the machine being equipped with a four-step cone. It seems incredible that a manufacturer would put such a tool upon the market.

It is obvious from the above considerations that some arrangement must be introduced that will subdivide the speed changes to a greater extent. Many mechanical devices have been brought out for this purpose and some of them have come into quite extensive use, more particularly those where the graduation from one condition of speed to the next (as regulated by gears or driving belts) could be subdivided into any number of parts. While these devices fill the requirements of being able of always obtaining the maximum speed, the complication and cumbersomeness of the device is not desirable and has prevented their coming into general use.

A letter from Mr. E. H. Symington was read before the Central Railway Club at their meeting at Buffalo, November 14th.

Mr. Symington, in speaking of electric drive in general, recommended, very strongly, alternating current. In speaking of variable speed motors he said: "With the advent of perfected speed changing devices there is less necessity for having speed flexibility in the motor itself. However, where there are a quantity of traveling cranes and other variable speed apparatus it is well to consider the advisability of a small direct current generating set for this purpose only."

We are still waiting for the advent of the perfected speed-changing device. However, we must admit that we cannot practically get a speed variation from an electric motor that will cover the entire working range of the average machine-shop tool. There are,

however, some tools in which this can be done; for instance, planers, slotters and machines of this character where the cutting speed of the tool is in constant relation of the work, regardless of its dimensions, and speed variation is only required for differences in material.

However, in that great class of tools in which the piece being operated upon is of circular form and the rotative speed varies directly with the diameter, a very wide range of rotating speeds are required. In this class of machinery it is practically impossible to cover the entire range by varying the speed of the driving motor.

Speed control is obtained in nearly every case by a combination of mechanical and electrical means, the motor range and gear ratios depending upon the machine and the average variation in diameters and kind of material handled.

Mr. F. O. Blackwell made the further statement in his paper that "With the three-wire system and a 100 per cent. variation in the motor speed by field control, we can obtain a 4 to 1 total variation, which, for general machine-shop work, is sufficient to cover a single operation on a given tool."

It may be and probably is true in most cases that a range of 4 to 1 will cover any single operation on a given tool, as stated by Mr. Blackwell. However, any system of variable speeds, to be applicable and to cover the ordinary working conditions, must be able to cover all possible speeds within the range of the tool. Since it is impracticable to get the entire range of speeds on the class of machinery last mentioned directly from the motor, a compromise must be effected.

We have in any given case a certain total range to cover in any given machine. Let us take, for example, a 48-inch engine lathe. Practice has shown that, even with the best tool steels at present obtainable, that it is desirable and almost necessary to have a cutting speed as slow as 16 feet per minute. This, of course, determines one limit of the speed range and is absolutely fixed, while the other limit of maximum speed at which the machine is to operate is not fixed and is determined for each particular case by the probable minimum diameter to be machined. If two inches be assumed as the smallest diameter and a maximum cutting speed of 100 feet per minute, at this diameter the maximum revolutions will therefore be approximately 150 times the minimum. This, therefore, is the total range of speed to be covered by the driving mechanism.

The question that next presents itself, and the one that cannot be determined by any hard-and-fast rule, is what portion of this

range will be covered by the variations of the speed of the motor, if a motor be used, or what other equivalent system will give equally as good results. The case cited in regard to the boring mill is almost exactly the same as the one under consideration. As stated, the builder solved the problem by using cone pulleys and one set of gears. It must be admitted, however, that this solution was very crude. On the other hand the question is, How many different speeds should be provided within this range and how will they be obtained? As stated, it is impracticable and well-nigh impossible to cover this range entirely by varying the speed of the driving motor.

The next step, consequently, is to use one set of back gears. This will call for back gears to be approximately $12\frac{1}{2}$ to 1 ratio; therefore, the limit of speed variation on the motor will be $12\frac{1}{2}$ to 1. The next combination available is to use two sets of back gears, which shall have equal ratios and shall gear into each other. In this case the variation of the motor speed will be as the cube root of the total variation, or approximately as 5.5 to 1.

This same line of reasoning may be followed, duplicating the gearing indefinitely, until the variations in speed are entirely taken care of in the gearing. This brings us to the perfected speed-changing device which has not yet made its advent.

The question is often asked, "What advantages are to be derived from driving machine-shop tools independently by electric motors?" The answer to this is that the principal advantage is in the ability to obtain any number of different speeds on the tool, thereby being able to work up to the maximum output at all times.

Mr. L. R. Pomeroy, of the General Electric Company, in a paper read before the Central Railway Club in Buffalo, November 14th last, quoted a celebrated authority, without naming the authority, as follows: "Where we have to decide whether we shall install one large motor or a number of small ones, I would give preference to the small motors down to a limit of 5 horse power for light machines and 10 horse power for heavy machines, this for cases in which the problem is one of distribution only. Where the introduction of motors could have any effect on the product, I would dismiss entirely the question of power and decide solely with regard to the convenience of operation afforded, and would not hesitate to put in the very smallest motors, mounted upon any kind of machinery, notwithstanding their greater cost and lower efficiency, if they even to but a slight degree increase the product of the labor of the shop. Gains in this direction cause other gains to sink into insignificance.

Mr. F. O. Blackwell, in his paper before the American Institute of Electrical Engineers, voiced the same sentiment, as follows: "The most important consideration in the electric driving of machine tools is to make the control of the tool as convenient as possible and arrange the system so as to permit small changes in speed, and consequently be able always to drive the tool at its highest possible speed and greatest output."

Another question that usually follows is: "But the tools in this shop are not designed to stand the higher speeds that the modern tool steels will permit; therefore, it is not possible to work them up to the maximum." A reply to this is, that if the machine will not stand the strains brought about by the high cutting speed of the modern tool steel, they still have their maximum, and there is just as good reason for working these tools to a maximum as any other tool to its maximum, although the maximum of these tools may be determined by a different factor.

We might state, however, that there is no reason why a machine tool that is adapted to do a certain work should not do this work at two or three times the speed. The reason for this seems obvious, in the fact that the strains on a machine are due entirely to the torque required to make a given cut. With this given cut the speed may be increased three or four times without producing any greater strains on the machine itself, because the torque remains constant. However, the horse power will increase directly in proportion as the increase in speed; and right here we have a factor that limits the ordinary belted machine tool—the belts will not pull the load. For instance, suppose that we have a given machine running with a belt on the largest step of the cone pulley on the machine, and taking a certain cut; assume the cutting speed be 20 feet a minute. If it is desired to increase this cutting speed to, say, 80 feet per minute, it is found necessary to put the belt on the smallest step on the cone on the machine. We at once encounter the difficulty that the belt will not begin to pull the cut. This is also true of the various mechanical speed-changing devices that have been introduced. Thus it will be seen that machine tools that were designed on the lines of the cutting speed of 20 feet per minute are not adapted at all to cutting speed of 80 feet per minute. However, they are not limited by the strength of the tool, but by the pulling power. Under these conditions it is only necessary to increase the pulling power of this machine to make it do four times the actual work that it formerly did. Here, again, is where the electric motor gets another big advantage.

Thus it is seen that there are two good reasons (and there are many more) for equipping machine-shop tools with electric drive, namely, the ability to at all times run the tool at its maximum cutting speed; secondly, ability to supply the necessary pulling power. Among the other numerous advantages in equipping machine-shop tools with electric drive might be mentioned the ability of placing machines in any position at will, making them, as it were, portable machines; absence of belts from the shop with their accompanying obstruction to light and accumulation of dirt.

In equipping machine-shop tools with electric drive there are many points to be considered in the selection of suitable motors. The first consideration, which directly affects the cost of the installation, is the highest permissible speed at which the motor can be operated.

After determining this point, the next point is the range through which the motor is expected to work, and after determining the range through which the motor is to operate, the next question is the determination of the method of obtaining this range of speed. A method of driving by electric motor, which will use the smallest motor, is to use a constant speed motor and get all the changes of speed by mechanical means. If it is desired to get different speeds by varying the speed of the motor when using so-called variable speed motor, there are two methods which practice has shown to be good. The method which first presents itself is varying the field strength of the motor. This is a very simple and effective way, but it is accompanied by the disadvantage of requiring a larger motor than would be required if the constant speed motor were used. For instance, if a speed range of 2 to 1 is required, and the motor is run from a source of constant potential, the motor would require to be four times as large as if it ran at the constant maximum speed. In other words, a motor that will give 1 horse power at 2000 R. P. M. maximum, and would also be capable of running at 1000 R. P. M. on a full field, would give 2 horse power at 1000 R. P. M. This motor would, of course, if run at full field strength at 2000 R. P. M. five 4 horse power and so on for any increased variation.

Mr. L. P. Pomeroy, in his paper before the Central Railway Club, spoke of interposing armature resistance in circuit of electric motor for various speeds. He said in that connection: "While it is obviously not advisable to presume in using the full range of such speed variation continuously, yet, in conjunction with step cones on back gears, any intermediate speed between the cones or gears can be exactly met by the introduction of very slight amount

of resistance or electric regulation, and under such conditions such variation is feasible and practicable. This represents the cheapest form of utilizing motor speed variation from a standpoint of first cost.

"Next in point of cost is the use of a special type of motor, giving 100 per cent. field regulation. By this type of motor the varying requirements of almost any tool can be met at a slightly increased cost over constant speed or standard motors. This, in the writer's judgment, is a rational method of meeting the case, as the range of speed is liberal and its cost moderate.

"A motor of ordinary design will not permit of any considerable field weakening without deleterious sparking at the commutator, but with a special motor having small armature reaction a variation in speed of 2 to 1 can readily be obtained, and when delivering a constant horse power the current will be approximately the same at all speeds, because the potential across the armature terminals is always the same. As the field current of a motor is only a small fraction of the total current, the efficiency of this method of control is practically the same at minimum and maximum speeds and allows the use of a much smaller controller, and renders it possible to get a greater number of running speeds than can be economically arranged for with any other control."

Mr. Pomeroy says that a motor with 100 per cent. field regulation, giving a speed range of 2 to 1, costs but little more than a standard constant speed motor to do the same work. As a matter of fact, this motor is four times as large as a constant speed motor to do the same work at the maximum speed. Furthermore, this motor, with 100 per cent. field regulation, if supplied with different voltages across its armature terminals, can be made to give another 100 per cent. speed variation by voltage regulation, thereby yielding a total speed variation of 4 to 1. Mr. Pomeroy says the speed variation of 2 to 1 is liberal, but if the same motor can be made to give, without additional cost, speed variation of 4 to 1, there would seem to be no reason why it should not be done, and it would be more than liberal. This same conclusion was arrived at by Mr. F. O. Blackwell in his paper. He said:

"In conclusion, I would say that, in my opinion, it will generally be found best to use motors with field control, allowing a total speed variation of 2 to 1 with the two-wire system or 4 to 1 with the three-wire system, believing that the four-wire system is too expensive for general application if the plants employing it are properly designed and equipped with large enough electrical apparatus."

It is seen from the foregoing there is a great desire to obtain as wide a range of speed variation in the motor as possible. What one person may consider sufficient in this respect would be considered entirely insufficient by another. The speed range through which a motor is to be operated for any given case is governed by a number of different considerations. The additional cost of the motor for increased range of speed variation will be offset by a saving in additional gearing and the ease of manipulation. The consideration of the last point is all-important. The time spent in juggling the gearing of any given machine will accumulate during the entire life of the machine, and means a constant expense, which may, under such circumstances, be much greater than the interest on an investment by which it would be eliminated in considering the difference in size and cost of motors to perform different functions. In this respect the writer has outlined the following explanation to use in conjunction with the curve attached.

If it is desired to have a motor that will give a speed variation of 4 to 1 by shunt field resistance, the motor would have to be sixteen times as large as a constant motor to do the same work at maximum speed. Thus it is seen that the limitation of shunt field control is soon reached. However, a combination of shunt field control and multi-voltage circuits gives an arrangement by which a comparatively wide range of speeds can be obtained without the motors being of excessive size. This may be readily understood by referring to curve sheet attached. Curve "A" represents change in horse power of any motor when running on a weakened field. This might be called a diminution of horse-power curve. For instance, on the curve we see that a motor that will give 5 horse power at 400 R. P. M. gives 1 horse power at 2000. From this curve we can determine the minimum size motor that will be required for any given case, using either shunt field regulation entirely, or combining shunt field regulation and multi-voltage. Suppose, for instance, that a given machine tool requires 1 horse power to operate it under all varying conditions of service. It might be stated right here that this is true of a very large class of machines which operate on cylindrical work, barring a slight change in friction load (through the different speeds of the machine, the cutting speed remaining constant the horse power remains constant). If, as above, a given tool requires 1 horse power under all conditions of operation, and it is required to have a speed range of 4 to 1, we can get this in two ways, one by using entire field regulation, which will require a motor 4 horse power at 500 R. P. M., or a motor can be used if two voltages, one

of which is double the other voltage, are available. This motor will be required to be 2 horse power at 1000 R. P. M. The horse power of this motor, due to reduction in speed, by reduction in voltage will decrease along line "K" so that at 500 R. P. M. it will give 1 horse power and also give 1 horse power at 2000 R. P. M. It is seen from the curve that with two voltages, one of which is double the other, that the range of speed of 4 to 1 is the maximum that can be obtained from a motor which will be worked to its full capacity at both the minimum and maximum speeds. If any greater range than this is required, under these conditions, a larger motor must be used. For instance, suppose that a speed range of 5 to 1 is required and the variation obtainable by changing voltages is only 2 to 1. Assume, as before, that the maximum speed is 2000 R. P. M., the minimum speed will be 400 R. P. M. Now, as 400 and 800 will be the speed variation by change in voltages, a motor will be required that will develop 2½ horse power at 800 R. P. M., or, in other words, where the curve "A" crosses the ordinate of 800 R. P. M. The horse power of this motor will decrease as all other motors, directly in proportion to its speed by reduction in voltage, will therefore be 1¼ horse power at 400 R. P. M., being, in this case, slightly in excess of the power at the slowest speed. The motor, however, in this case would be equivalent of a 3.1 horse power at 1000 R. P. M., or more than 50 per cent. larger than a motor to do the same work with a speed range of 4 to 1.

Mr. N. W. Storer, of the Westinghouse Electric and Manufacturing Company, in a paper read before the American Institute of Electrical Engineers, in New York, November 21st last, in defense of the system as outlined above, said:

"The operation of motors on this system is most satisfactory. The fact that the speed is increased so much by weakening the field might lead some to think that the commutation would suffer, but such need not be the case. An example will demonstrate the truth of this statement. A certain machine requires a 5 horse-power motor to operate it with a speed variation of 1 to 4, say, from 375 to 1500 R. P. M. On the three-wire system this motor will be a standard 10 horse-power 220-volt motor, operating normally at a speed of 750 R. P. M. Run with full field strength on the 110-volt circuit, which has only half its normal voltage, the motor will easily stand an increase of speed of 60 per cent. to 75 per cent., bringing the speed up to 600 or 650 R. P. M. When it is changed to the 220-volt circuit, it will have its normal capacity for 10 horse

power at 750 R. P. M.; but only half load is required, and it will commutate this as easily at a speed of 1500 as it would 10 horse power at 750, because both field strength and armature current will be divided by two. From this it may be seen that when the motor is running at full armature current the voltage is only one-half the normal voltage. When the motor is operating at full voltage, the armature current is only one-half the normal current. If speed variations of 1 to 6 are required, they can be secured by a very slight increase in the normal field strength of the motor."

The last sentence of this quotation from Mr. Storer's paper would lead one to believe that there was but a slight difference between a motor that would give a speed range of 6 to 1 and a motor that would give a speed range of 4 to 1. As a matter of fact, the motor that would give a speed variation of 6 to 1 on the three-wire system, as outlined by Mr. Storer, would be two and one-fourth times as large as the motor to give 4 to 1 on the same three-wire system. This is easily deduced from the curve shown. However, if a different ratio of voltages are available to operate the motor upon, a motor that would give a 6 to 1 variation would be only 50 per cent. larger than a motor to give a range of 4 to 1.

Assume that a speed range of 10 to 1 is required, with, as before, 1 horse power at all speeds, the motor which would fulfill the conditions of being worked to its full capacity at the minimum and the maximum speeds would be the motor whose horse power would be represented by the line "G." This motor would have as maximum rating 3.2 horse power at 640 R. P. M., or a range of speeds by voltages 3.2 to 1, so that the range of voltages must bear this ratio. A motor that will give this speed variation by shunt field regulation entirely would be 10 horse power at 200 R. P. M. This motor would give 32 horse power at 640 R. P. M., or would be ten times as large as a motor giving the same range operating on combined system of multi-voltage circuits and shunt field regulation. Thus it would seem that shunt field regulation is prohibitive for any such speed range as 10 to 1.

In explanation of this curve, it might be said that the lines representing the change of horse power due to change in speed is not strictly according to change in voltage, but change in revolutions per minute, but it varies so little from this that no great error will be introduced in using these curves to represent the range of voltages as well. The curve "A," representing the decrease in horse power due to change in speed by shunt field regulation, is strictly correct.

In further explanation of use of the curve attached, in any given instance, if the speed range has been determined, as well as the maximum and minimum speeds, the full speed full voltage rating of the motor can be ascertained from the curve as follows: Locate on the curve "A" the point corresponding to the maximum speed which it is desired to operate. Trace to the left from this point on the scale of ordinance and read the horse power.

This horse power may not be the actual horse power in any given case, but it can be assumed as proportional to the actual horse power required.

Again trace from the minimum speed which is desired to operate vertically until the horizontal line which represents the same horse power that was determined from the curve "A" is reached. Through this point draw a straight line from the origin "O," intersecting the curve "A." From the point of intersection trace downward to the base line, and the full voltage full speed of the motor will be found.

Now, the ratio between the minimum speed and this speed which is found, which is full voltage full speed of the motor, will be the ratio of the voltages which will give the minimum size motor for the given work.

To illustrate, let us assume that it is desired to operate the motors at a minimum speed of 350 R. P. M., a maximum, to 2100 R. P. M.

We have, therefore, rating of approximately 1 horse power from the curve "A." Tracing vertically from 350 R. P. M. to the line which corresponds to 1 horse power, and drawing a straight line from the origin through this point until it intersects with the curve "A," we find that the full voltage full speed of the motor should be 825 R. P. M. Now, it is not feasible to make motors for all kinds of speeds, so, in selecting a motor for this case, we would choose 900 R. P. M.

The ratio between 350 and 900 is 2.6, approximately. This would, therefore, be the ratio of the voltage (maximum and minimum) to be used. The motor, however, will be slightly in excess of the required power at full speed, as would be shown by tracing through point which was reached, corresponding to 900 R. P. M., curve parallel with curve "A." It is at once seen that this motor will be 2½ horse power at 900 R. P. M.

However, assume that it is desired to get this same speed range, the ratio of voltages being 2 to 1. As the minimum speed will be given by the lowest voltage, the highest voltage will, of course, give twice that speed, or 700 R. P. M.

From the curve "A" it is at once seen that the smallest motor that can be used to give 1 horse power at 2100 R. P. M. will give 2.8 horse power at 700 R. P. M.

This is a point which is found by tracing vertically from base line at 700 R. P. M. to the curve "A."

Following the line "H" toward the origin until we come to the point that corresponds with 350 R. P. M., we see that this motor will give 1.4 horse power at 350 R. P. M., or is in excess of the power required at this speed.

In the other case a motor at 900 R. P. M. had more power than required at the maximum speed. However, the motor operating at 900 R. P. M., giving 2.6 horse power, will be exactly the same motor as the one operating at 825 R. P. M., which, as shown by the curve, is the minimum size motor that will fulfill the conditions.

The reason why it can be run at 900, giving slight excess of power at maximum speed, is because the range of voltage will permit of it.

In comparing the size of the motors required to do given work, one at full voltage full speed of 700 R. P. M., the other at full voltage full speed at 900 R. P. M., would give 3.6 horse power at 900 R. P. M., as against 2.6 horse power at 900 R. P. M. of the motor having the wider range of voltage.

The multi-voltage system, consisting of four wires and three different voltages, having a total range of voltages of about 4 to 1, while fulfilling the conditions for which it was designed, is not being worked to its utmost capacity as regards speed range. That is to say, that where a range of $7\frac{1}{2}$ to 1 is now obtained, one would be able, as far as the motor is concerned electrically, to get a range of 16 to 1. The reason for this is that the motor is not speeded up above its full field full voltage speed to as great an extent as it might be, and still develop the same power that it develops at its minimum speed.

As seen by the curve referred to, the available range of speed for constant horse power on any given motor is as the square of the ratio of the voltages on which it is operated. That is to say, if a speed range of 9 to 1 is desired, the voltages need have a ratio of only 3 to 1. From this it is at once observed that it is unnecessary to use a range of voltages of 4 to 1 for a speed range of $7\frac{1}{2}$ to 1.

In referring to constant horse power, it is not to be understood that this horse power is the maximum horse power of the motor. It is the maximum horse power, however, that the motor will yield

at its minimum and maximum speeds. At all intermediate speeds it will have an excess power.

All of the limitations in regard to speed range for any given range of voltages is based on using a motor of the smallest possible size to develop at its minimum and maximum speeds the power called for. This applies only to motors delivering practically a constant horse power at all speeds.

Great care should be exercised in selecting motors for different machines to determine whether the horse power required is practically constant or varies with the speed. In most machines of a reciprocating nature, slotters, shapers, planers, etc., the power required varies with the speed as the power is consumed in the machine in reversals and not in the actual work being done. In cases of this kind the motors should be specified to run on full field full voltage at the maximum speed required, getting speed variation by the use of the multi-voltage circuits and shunt field resistance for intermediate speeds. That is, no resistance is to be used in the shunt field of the motor when the motor is operating on full voltage.

Some trouble has been encountered in getting speed variation on the class of machinery in which the horse power varies with the speed by using shunt field resistance. This will be entirely overcome by the arrangement proposed.

In some installations the speed range, as well as the number of different speeds, is very much less than has been gotten with the four-wire system of multi-voltage. Where the range of 7½ to 1 with twenty-six different speeds has been obtained by the four-wire multi-voltage system, the range has been 5 to 1 with six and eight speeds on other systems. It is evident that such a reduction in speed range and in the number of speeds must naturally reduce the cost of an equipment, at the same time very materially reducing its efficiency.

In the case of a speed range of 4 to 1, considering a maximum speed of 1450 or 1500 R. P. M., as in the previous case, the minimum speed, instead of being 200, would be 300 to 375 R. P. M., and as the minimum speed determines the size of the motor for a given horse power, the motor should be just that much smaller.

Mr. F. O. Blackwell, in his paper before the American Institute, said: "It is therefore seen that a motor to be used on the multi-voltage system will have to be sufficiently large to carry its maximum horse power at the minimum potential, or, in other words, at, say, 40 volts on a 250-volt system, the motor will have to be six times too large when working at its minimum potential."

This is, of course, strictly true, and applies equally as well to speed regulation obtained by shunt field resistance, only in a very much magnified degree. While a motor will be six times too large when operating at six times its speed, the speed being increased by an increase in voltage in order to get the same range by shunt field regulation, the motor would require to be thirty-six times the size it would be if only operating at the one maximum speed. This in itself is sufficient proof of superiority of the system of getting variable speeds by variable voltages over the system of shunt field regulation exclusively.

From this it follows that a motor whose speed is to be varied by change in voltage, field excitation remaining constant, will be directly proportional in size to the change in speed, while a motor whose speed is to be varied by change of field excitation will be in size as the square of the change in speed.

In conclusion, the writer would indicate a few rules to be used in determining relative sizes of motors for constant horse power application:

First.—The total range of speed, using both variable voltage and field regulation, will be as the square of the range of voltages.

Second.—Change of horse power will be directly proportional to change of voltage on armature, field being constant.

Third.—Change of horse power by change of field strength will be inversely proportional to change in speed, voltage on armature remaining constant.

Fourth.—The relative size of motor as referred to the maximum speed will be directly proportional to its speed variation when using variable voltages.

Fifth.—The relative size of motor as referred to the maximum speed will be as the square of the speed variation when using field regulation.

Ferdinand Schwedtmann.—In my remarks on the subject of electric driving of tools and other shop machines I shall endeavor to follow the lines and arguments advanced by Mr. Layman.

The advantages of electric transmission over mechanical means, such as shafts, etc., is too apparent to require any further argument.

We need, therefore, consider and compare only the various means of electric drive under the following divisions and subdivisions:

A.—Group system.

A 1.—Comparison of alternating current motor with direct current motor for group driving.

B.—Comparison of the various systems of direct current motor drive for individual machine systems.

C.—Means of securing the same results with alternating current motors that can be obtained with the best direct current motors.

Returning to A, or group system, as defined in Mr. Layman's paper, I think that in most cases the advantage of using one motor for a number of machines is mainly in saving of first cost. There are, however, cases in which larger electric efficiency is added to saving in first cost without affecting ease of handling. I refer particularly to the use of high-speed machines with great variation in consumption of power, such as large emery wheels. In my experience the best results have been obtained with four to six such machines connected to one motor and the addition of a heavy flywheel either on motor or counter shaft.

Referring to A 1, it is evident that for group drive either standard alternating or direct current motors are suitable, as nothing is depending on starting torque or speed regulation.

Under B we have to consider:

B 1.—Standard direct current motors with speed variation by means of rheostatic control in either armature or field circuit for varying speed of machine.

B 2.—Constant speed direct current motors and mechanical means between motor and machine or tool for altering speed of the latter.

B 3.—Multiple voltage direct current motors or motors in which variation of speed is obtained by changing without use of resistance voltage across the armature or fields.

It has already been pointed out by Mr. Layman that motors under B 1 are very inefficient electrically compared with other motors. Another and even more serious objection to motors with rheostatic control in the armature circuit is the fact that the speed of motor changes with the work done. For instance, the speed of a lathe would change with the depth of the cut. This drawback is serious enough to make the use of motors with rheostatic control commercially impossible for 90 per cent. of shop work.

Mr. Layman has made a strong argument for motor systems described under B 2. His argument points out that mechanical devices exist by the use of which the machine speed can be adjusted as easily and effectively as by electric control of motor, and that the size and first cost of motor is much smaller.

In answer to this argument, I desire to state that I have seen many mechanical speed-changing devices in the last fifteen years, but so far none has stood the test of time. Many of these devices

are very ingenious, but low efficiency or complicated construction have invariably cut short the life of all.

The handling of the best of the mechanical speed changers that I have had experience with does not compare with the ease of best electric controllers. The particular device described by Mr. Layman is, I believe, only intended for very small amounts of power.

The argument of the lower first cost should not be given too much weight, as for shop work efficiency of output and ease of handling far outweigh first cost.

For all the various reasons given, I point to system described under B 3 as the most satisfactory for the greater percentage of shop work. Mr. Cooper has talked very interestingly on the various ways of multiple voltage control. I think that, after all, the number of wires and voltages are steps of refinement which need not be considered here.

The advantages of *any* kind of multiple voltage control (B 3) have been pointed out sufficiently by Messrs. Layman and Cooper, and I will refer to some of these advantages only in comparison between B 3 and C.

Alternating current is for various reasons installed in most modern central stations.

Almost all work that can be done by continuous current can be done as well, or better, by alternating current. The one great exception is variable speed motor service.

Even in this direction I saw some very interesting things during my trip through Europe last summer. Ganz & Co., in Budapest, which firm has done so much pioneer work in the application of alternating current, are running their whole shop with two-speed alternating current motors. The motors used are their standard two or three-phase machines. Wires from two generators furnishing fifty and twenty-five cycles respectively are taken to each motor. On the higher frequency the motor runs without transformer. On the low frequency a transformer is inserted, reducing the voltage to a point where the best efficiency and magnetic density is obtained in the motor. We have, therefore, in this system all the advantages of a two-circuit multiple voltage control system.

At the shop of the Oerlikon Company, in Switzerland, I saw the same result obtained with alternating current in a different way.

Only one set of wires from one generator was taken to the alternating motors. The motors had short-circuited armatures and two sets of field winding, one with double the number of poles of

the other. Nearly the whole Oerlikon shop is driven with this system.

It can be seen plainly that a combination of the two systems of Ganz and Oerlikon might give all the advantages of the best multiple voltage control system, and the question which is best would depend on cost and electric efficiency.

It is my opinion that in a short period we will see variable speed alternating current shop drive system equal in every way to the best direct current multiple voltage control system.

DETROIT SEWER SYSTEM.

By W. C. King, Member Detroit Engineering Society.

[Read before the Society, December 26, 1902.*]

The problems that have entered into the construction of the sewer system of this city are in no way peculiar or difficult, inasmuch as the greater part of the surface has a gentle slope as we pass toward the drainage district, from the river, where the sewers empty, giving quite uniform depths for the main sewers and enough, except near the outlets, to meet every requirement.

In the near future, however, when the limits of the city are extended to take in flat territory to the east or west, new problems will present themselves, and we shall probably have to abandon the present gravity system.

But, if the drainage is not as perfect as the natural conditions, I think we can justly lay the error upon those who have gone before. Our fathers did not dream of a city like the Detroit of to-day when they built those old sewers in the streets of "Governors and Judges Plan" fifty or sixty years ago, and, perhaps, if they had dreamed of it, they would not have cared to assume the great expense of a construction deep enough and large enough to drain the great stretches now included within the city.

It has been necessary, however, to utilize this old construction, money for sewer purposes being always grudgingly given, and now this down-town district looks like a patch on a new garment.

The sewer system of this city is designed to carry storm water, as well as sewage proper. The main sewers are generally laid in each alternate north-and-south street, so that each shall carry the drainage from a row of blocks on each side. These main sewers are built of brick, with two or three rings, depending upon the diameter of the section. The form of section is usually circular, unless the conditions call for an area of section less than that of a five-foot cylinder, when it is changed to an egg form, believing that the narrow bottom of such a form will cleanse itself better with a light flow than the broader invert of the cylindrical shape.

The grades used depend upon the available total fall, and range from 0.05 to 0.25 per 100 feet. A grade of at least 0.10 per 100 feet is considered desirable, and a flatter grade is never used if it can be avoided.

*Manuscript received February 13, 1903.—Secretary, Ass'n of Eng. Socs.

The area of the section is then computed by the well-known formula:* "The quantity in cubic feet per second per acre reaching the sewer equals a coefficient according to judgment multiplied by the average cubic feet of rainfall per second per acre during heaviest fall multiplied by $\sqrt[4]{\frac{S}{A}}$; where S is the average ground slope in feet per 1000 feet and A is the number of acres drained."

The maximum rate of rainfall taken into account in this city is 2 inches per hour, and the factor representing the part of the total rainfall that will reach the sewer on unpaved streets is usually taken at 0.5, and on paved streets, 0.75. The slope of the surface is very liberally taken at 2 feet per 1000 feet.

The largest sewer we have in the city is a 9-foot cylinder in Woodward Avenue. This sewer will have to carry the drainage of a section approximately from the railroad crossing to the six-mile road, one-half mile wide on each side of the avenue.

These main sewers are usually constructed in tunnel, if the earth materials and depth will allow. Shafts are excavated 8 to 12 feet square at intervals of from 300 to 500 feet, and securely timbered to prevent caving. The tunnel is then extended in both directions until these shafts are connected, the earth being taken out during the day and brick laid at night.

The outlets of these sewers at the river were formerly submerged, but this is believed to have been a mistake, for the river water, which extends in such cases far up into the sewer, retards the current and causes a deposit which in time becomes a serious matter. To avoid this and, at the same time, to give all the advantages obtained from a submerged outlet, more recent sewers have been kept above the river water till near the outfall, when a steeper fall is given, submerging the end only.

Such an outlet was constructed recently near the water works pumping station, and, although many submerged sewers were working in the city, as soon as a complaint that bad odors were coming from the manholes of this sewer came to the department, an order was given to have the outlet opened to the air. This was done at considerable expense, but no relief came from the change, and it is now known that the odors were not caused by a lack of air from the river, but from decaying vegetable matter carried into the sewer far up the line, where there was not enough dry weather flow to absorb the gases.

These outlets are built on a floor supported on piles driven about 8 feet apart, capped with 12 x 12-inch timbers laid longitudinally. On these timbers are laid two layers of 3-inch plank,

*Trautwine, 18th edition, p. 575.

which carry the brick work and concrete filling. A permanent dam is constructed around this work, and, after pumping out the water, the sewer is extended to any desired point, which is now the new harbor line.

Up to tne year 1892 the lateral sewers were built of brick, one ring, 15 x 20 inches, egg-shaped. Since that year they have been built of vitrified crock, with Y branches for house connections.

The sizes of these sewers, as well as of the main sewers, are computed by Kutter's formula, placing "n" at 0.012 for crock and 0.015 for brick. Wherever it is possible to get a one per cent. grade it is used, but we have to resort sometimes to as low as four-tenths of one per cent.

The crock sewers have given very little trouble, and we have good reason to believe that they are much superior to the brick ones. It is only fair, however, in making the comparison, to remember that the brick construction is older and was not laid with so much care and under as good inspection as is now used on this construction.

The brick manholes, which are now built at nearly all ends and angles of the crock sewers, and lamp holes of 8-inch pipe at intermediate points, provide for inspection when the sewer is completed and for flushing and locating obstructions in the future.

The grades of these sewers are very carefully given, so that no low places for sediment will occur. The crock is frequently tested with the instrument and continuously laid on a grade given by range bars in the hands of the inspector.

The sewer work here is practically all done by contract, the bids being based upon plans and sections furnished by the Department of Public Works. There is no attempt to show the kinds of earth material and no allowance is made for mistakes of contractors. But there is little trouble here with earth material, the most of it being blue clay, with some quicksand in known localities.

The main sewers are built out of a fund appropriated each year by the Common Council for that purpose, but the lateral sewers are petitioned for by owners and paid for by a local assessment on the abutting property. The law says that this tax shall be apportioned according to the *benefits*. This subject of benefits is one that is very interesting, especially to one who has some of these special assessments to pay, and usually each interested party has a method of his own of getting at just what the benefits in his case are, and two seldom agree.

But what are the benefits derived from a lateral sewer? First and apparently most important, all the water taken into the house from the water supply of the city goes out again and is carried away by the sewer; second, the roof and cellar drainage must be taken care of, and, third, the drainage of the lot on which the house stands.

It can easily be seen that any system of assessing that would cover these three benefits would be complicated and impracticable. The city does not want to be bonded and overburdened for purely local things, and it is evidently wrong to exempt vacant property at the expense of the occupied property.

The plan used in this city is simple and gets about as near to justice as it is possible to get. The assessment is based entirely upon one benefit, that of the drainage of the lot, which at the time of the construction of sewers is the only benefit existing and upon which a roll could possibly be computed.

Being consistent in this matter of assessing the abutting property, the city comes in for its share, for it owns the street through which the sewer reaches the main. The area of street drained into such an arm is variable and quite indeterminate, and it was decided to let the city pay for that part of the sewer represented by the ratio of the length of the arm to the length of the whole sewer. This share is then taken out of the total cost and the balance distributed on the lots.

The city furnishes the manhole covers and cement, to insure uniform material and a liberal use of cement, and these items are apportioned to and paid for by the city and lots as detailed above.

ABATEMENT OF THE SMOKE NUISANCE.

Report by Committee, Engineers' Society of Western New York.

[Read before the Club, January 6, 1903.*]

At the regular meeting of the Engineers' Society of Western New York, held January 6, 1903, at their rooms, 533 Ellicott Square, the following report of the committee appointed April 3, 1902, by the President of the Society to consider the subject of the "Abatement of the Smoke Nuisance in the City of Buffalo, N. Y.," was read by Mr. Louis H. Knapp, chairman.

Buffalo, N. Y., January 6, 1903.

Mr. President and Members of the Engineers' Society of Western New York:

Your committee, appointed to consider and advise regarding the "Abatement of the Smoke Nuisance in Buffalo," reports as follows:

The problem of the prevention of the formation of smoke is an old one, and has been successfully solved in several of the modern furnaces and stokers. In fact, when there is an united co-operation between the users and the engineer the volume of smoke produced is so small as to be hardly appreciable.

"Absence of smoke in chimneys" means perfect combustion in the furnace, and it is to the advantage of the manufacturers to accomplish perfect combustion; to insist on having smoke abated does not mean the driving away of manufactures. It means that the consumption of fuel must be accomplished properly, and to do it properly is to do it economically. The manufacturers should want to do it, and, as a rule, they do.

Buffalo, on account of its location, is comparatively a clean city. This is largely due to natural causes. The location of Buffalo at the eastern end of Lake Erie and directly in the path of a nearly constant wind blowing down the lake and bringing a constant supply of clear and practically sterile air is the cause of this fact.

Comparatively few factories, railroads or docks are located between the lake or river and the residence portion of the city.

The water front from Genesee Street to Black Rock is now comparatively free from smoke producers. The westerly wind, which is our prevailing wind, blows in a direction almost parallel to Genesee Street.

*Manuscript received January 16, 1903.—Secretary, Ass'n of Eng. Socs.

We suggest that efforts be made to keep the water front north from Genesee Street to Scajaquada Creek at Black Rock as free as possible from smoke producers, and also to reduce the amount of smoke production to a minimum in the large residence section of the city located north of Genesee Street and south of the line, A-B, parallel to Genesee Street extending northeasterly from Scajaquada Creek at Black Rock to the city line. This section of the city one would call the residence section, and its beauty and freedom from smoke should be most jealously preserved.

The business, manufacturing, railroad and dock section of the city is now located very largely south of Genesee Street, and in small part at Black Rock.

We suggest that greater latitude as to the amount of smoke produced be allowed in the northerly and southerly manufacturing sections of the city than in the central or residence section.

We wish in every way to encourage the manufacturing and transportation interests of our city, and at the same time maintain the beauty and healthfulness of its residence section.

We therefore suggest, as the most practical way of doing this, the division of the city into separate sections as regards the smoke nuisance.

In Cleveland over five per cent. of smoke in the residence and business sections is considered objectionable, while up to ten per cent. of smoke is considered allowable in the manufacturing districts, dense black smoke being taken as one hundred per cent.

In this city very little smoke is produced by domestic or other fires not used to produce steam. We will therefore leave them out of consideration and confine our suggestions to fires used under boilers.

Three elements are to be considered in the production of smoke—fuel, apparatus and labor. Of the fuels in common use, gas, anthracite or hard coal and coke produce little, if any, smoke, even if used with poor apparatus operated by careless and unskilled labor. Where the use of such fuel is insisted upon, as in the City of Washington, there is no smoke nuisance.

Soft, or bituminous, coal can be had in Buffalo at a much lower cost than any other fuel, and the smoke nuisance is almost entirely due to its use in unsuitable apparatus carelessly handled. If skillfully and carefully handled, apparatus may be had that will burn soft coal under boilers with very little smoke.

The arrangement of the apparatus for burning soft coal should be subject to the approval of an expert engineer. In Cleve-

PLAN OF BUFFALO, SHOWING RESIDENCE DISTRICT.

land a supervising engineer is employed by the city for this purpose, and we recommend that such an engineer be employed in Buffalo.

Careful and skillful firing alone will greatly reduce the smoke nuisance.

In Cleveland Prof. C. H. Benjamin, the supervising engineer, reports cases where the amount of smoke has been reduced to one-quarter of the former amount, and the coal bills reduced from fifteen to twenty-five per cent. by suitable apparatus and careful attention to firing.

It has been suggested that an arrangement of granting a certificate to a fireman who keeps the smoke from his boilers below a certain percentage might secure his co-operation. The possession of such a certificate would be of value to him, as it would show him to be a careful and economical fireman and entitled to more pay than one who could not show such a certificate.

As an aid in the abatement of the smoke nuisance, we suggest that a set of rules and suggestions as to the most approved methods of firing boilers be printed and tacked up in every boiler room in the city. Such information would help educate the owners and firemen of steam plants as to the most economical, as well as smokeless, methods of firing.

Similar suitable printed rules and suggestions, especially adapted to locomotive firing, could also be placed in each locomotive.

We do not wish to recommend any particular boiler setting or smoke consumer for burning soft coal.

For the benefit of those who wish to consider the subject more in detail we give below a list of articles in the technical press referring to this subject. (See Appendix.)

Respectfully,

(Signed) Louis H. Knapp,
(Signed) George B. Bassett,
(Signed) H. J. March.

Accompanying the report are the following documents:

I. Statement of U. S. Weather Bureau relative to direction of wind in Buffalo for last ten years.

II. Map of city of Buffalo, showing location of resident district.

III. Smoke Ordinance, Philadelphia, Pa.

IV. Smoke Abatement in Cleveland, Prof. C. H. Benjamin, Amer. Mchst.

V. Report of Wm. H. Bryan, St. Louis, to Board of Education, February 3, 1902.

VI. Report of Prof. C. H. Benjamin to City Counsel of Cleveland.

VII. The Smoke Nuisance, by John M. Hartman, read at Franklin Institute, September 3, 1902.

VIII. About Smoke Consumers, by D. B. Dixon, American Manufacturer.

IX. Smoke Consumption at the University of Chicago, by M. W. Lee, from "Shop Talk."

APPENDIX.

"Report on Smoke Prevention," by C. A. Landreth, Nashville. (No publisher given), 1893. (Supplement to the State Board of Health Bulletin.)

"Smoke Prevention: A paper read before the St. Louis Commercial Club, October 20, 1888," by Robert Moore, St. Louis, R. P. Studley & Co., 1888.

"Report of the St. Louis Special Committee on Smoke Prevention," St. Louis, W. H. O'Brien & Co., 1892.

"Annual Report of the Boston Street Department," 1893-4. Boston 1893-4. (Contains report on "Smoke Nuisance." Annual report 1893, p. 151; 1894 p. 103.)

"Smoke Abatement in St. Louis," by W. H. Bryan, Journal of the Association of Engineering Societies, December, 1901.

"About Smoke Consumers," by D. B. Dixon, American Manufacturer and Iron World, Dec. 19, 1901.

"Abatement of the Smoke Nuisance," by C. H. Benjamin, C.E., American Machinist, Jan. 23, 1902.

"Smoke Consumers," by W. H. Bryan, Cassier's Magazine, Nov. 1900.

"Smoke Consumption at the University of Chicago," by M. W. Lee.

"Reports of John M. Hartman, Phil'a, Pa." Read at Franklin Institute, September 3, 1902.

AT BUFFALO LIBRARY, BUFFALO, N. Y.

Barr, William.

Catechism on the combustion of coal and the prevention of smoke, N. Y. 1900. 621.2, 91.

Report of the Smoke Abatement Committee, 1882. London, 1883. 967 B-3.

Robinson, C. M.

Injury of smoke (In his Improvement of Towns and Cities). 1901. p. 60-3. 710, 15.

Suppression of Smoke (In his Improvement of Towns and Cities) 1901, p. 57-60, 260. 710, 15.

Van Horne, Robert M.

Report of the supervising engineer (of Cincinnati) on the abatement of smoke for the year ending December 31, 1893. Cincinnati, 1894. 31 pp. 697, pamp. 6.

MAGAZINE ARTICLES.

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Apparatus for consuming smoke. Sci. Am. Supp. 47:19419. (99)

Apparatus for filtering air and smoke. Sci. Am. Supp. 49:20371 (1900)

Note on progress of smoke abatement in Glasgow. Am. Mach. 23:1:21 (1900)

Possibilities of electrical smoke dispersion (J. Wright). Pub. Opinion 29:784 (1900)

Practical experience with preventive measures. (C. H. Benjamin.) Cassier, 20:129 (1901)

Practical lesson in smokelessness. American Mach. 24:part 4:1325 (01)

Pratt pressure transformer. Sci. Am. Supp. 52:21618. (1901)

Prevention of smoke by the use of pulverized fuel. Eng. Mag, 18:125. (1899)

Pure air and clear skies. Outlook 61:106 (1899)

Russell's smoke preventer. Sci. Am. Supp. 48:19811 (1899)

Smoke abatement (W. H. Bryan) Cassier, 19:17 (1900)

Smoke abatement. Engineering. Aug. 7, 1896.

Smoke abatement. Eng. Mag. 22:924, Mar. 1902.

Smoke abatement in Cleveland (C. H. Benjamin) Am. Mach. 25:130 (1902)

Smoke abatement in St. Louis (W. H. Bryan) Jo. Assn. Eng. Socs. 27: 215-31 (1901) Includes test of ordinance.

Smoke Consumption and economy of fuel (F. H. Mason) Sci. Am. Supp. 48:19752 Aug. '99.

Smoke consumption and smoke prevention (Tecumseh Swift) Am. Mach. 23: part 2:1093 (00) L.

Smoke Nuisance. Jo. Franklin Inst. 144:401 (97)

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Smoke nuisance 600 years ago. Cassier. 16:86 (May, 1899)

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Smoke Prevention. W. H. Booth Am. Mach. Sept. 8, 1898.

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Smoke prevention and smokeless furnaces. Eng. News Jan. 2, 1896.

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Suppression of smoke (R. H. Thurston) Sci. Am. Supp. 47:19367 (99) Science n. s. 9:55-7 (99)

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Butte City. Schemes proposed for getting rid of sulphur fumes. 93:1:9 62, 207.

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Discussion by O. A. Landreth. 93:1:547, 93:2:73, 96:1:4 (Ill.) 9, 10, 92

Kansas City specifications and bids. 94:1:540.

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Omaha ordinance of 1893, Reynolds furnace tested by Mr. Bryan. 96:1: 5 (Ill.)

Ordinances of various cities. 97:2:111.

Philadelphia. Board of Health requested Franklin Institute to investigate question of smoke prevention. 97:2:111.

Tests of Hawley down draft furnace at St. Louis and Toronto. 96:1:5 (Ill.)

Test of Sargent apparatus. 92:2:436.

Scranton city ordinance. 98:2:200.

Steam jet apparatus for boiler furnaces. Hutchinson apparatus. Buchanon system. 91, 1:314. (Ill.)

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There are also numerous references under Stokers, Mechanical, especially to 96:1.

Note 1901:1:471.

Boston circular 1901:1:441. (Report of investigation by Mutual Boiler Insurance Co.) Also 1901:2:136.

Smoke prevention at Cleveland (including test of ordinance). 1900:2:415.

St. Louis ordinance 1901:2:249.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a

synopsis of the other general transactions of the Board of interest to members, shall be published in the JOURNAL OF THE ASSOCIATION.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published, and shall forward the same to the Secretary.

SEC. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interet and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.
Engineers' Club of Cincinnati, January, 1899.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

For the Engineers' Club of Cincinnati see footnote to Appendix F, Secretary's Annual Report for 1902, page 57.

Annual Report of the Chairman of the Board of Managers.

To the Board of Managers Association of Engineering Societies.

GENTLEMEN:—I have the honor to present to you my report for the year 1902, and to transmit therewith the report of the Secretary for the same period.

The Secretary's report shows the gratifying result that the cost of the JOURNAL per member has decreased 19 per cent. and that the net assets are thereby increased 21 per cent. There has, however, been a slight decrease in the membership and in the amount of matter sent in for publication. The latter decrease the Secretary accounts for from the fact that the members are too busy in their several lines to take the time to write papers, and if such is the case it is as gratifying to the members probably as would be the appearance of their papers in the JOURNAL. Still I hope that the members will be able to contribute more largely this year to the JOURNAL, without in any way decreasing their present activity in the lines of business.

I call your attention to the Secretary's reference to the arrangement, by which 90 per cent. of the gross receipts for advertising is refunded to the Society securing advertisements, and urge the members of the Board to present this matter to the various Societies, so that the advertising matter may eventually make the JOURNAL self-sustaining.

In concluding I desire to call your attention to the fact, as I have also done in former reports, that the satisfactory results obtained in the publication of our JOURNAL, and the increased circulation of the same, are entirely due to the work of the Secretary, and that it is the duty of the members and of the Societies that are represented by them, to render him every assistance in their power, and to supplement his work by such efforts as will make the JOURNAL more desired by outsiders and thus bring in an increased membership.

Thanking you for the honor you have conferred upon me in the last year, I remain,

Very respectfully,

JAMES RITCHIE, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 31, 1902.

Mr. James Ritchie, Chairman,

413 Chamber of Commerce, Cleveland, Ohio.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1902, and of the condition of the affairs of the Association at the present time.

These data are concisely stated in the following statistical appendixes:

A. Statement of receipts and expenditures during 1902.

B. Estimate of assets and liabilities at the close of 1902.

C. Detailed statement of cost of JOURNAL during 1902, by months.

D. Net cost of JOURNAL during 1902.

E. Statement of material in JOURNAL during 1902, by pages.

F. Comparison of mailing lists of the JOURNAL at the close of 1901 and of 1902, respectively.

G. Comparison of conditions, 1894 to 1902, inclusive.

H. Comparison of conditions, 1900, 1901, 1902.

Appendix H, deduced from appendixes C and F, shows a small decrease (say from 3 to 4 per cent.) in the aggregate membership and in the amount of matter published, but also a large decrease (22 per cent.) in the net cost of the JOURNAL.

This involves a decrease of 19 per cent. in the cost per member for the year, bringing this item to $1.68, instead of $2.07, as in 1901. This decrease accounts for the gratifying increase of 21 per cent. in the net assets, which have increased from $2062.72, at the close of 1901, to $2601.19 at the close of 1902, the assessment having been maintained at $2, as in recent years.

The decrease in cost of JOURNAL is due partly to the slight decrease in amount of matter published, and partly to the reduction of 62 per cent. in the cost of illustrations. Notwithstanding the advance in printers' charges, which went into effect during 1900, the gross cost of the JOURNAL per member per 1000 pages, for 1902 ($2.36), is almost as low as it has been for any year since 1893; it having been less only in 1898 and 1899, when it was $2.28 and $2.29, respectively.

Appendix G shows a slight falling off (5.6 per cent.) in the volume of papers published. The number of pages of papers (610) published in 1902 is 32 less than the average number for each year from 1894 to 1902, inclusive.

In my report for 1901 I again called the attention of the Societies to the arrangement by which the Association refunds, to any Society, 90 per cent. of the gross receipts from advertisements secured by such Society for the JOURNAL of the Association. This large percentage practically amounts to the net receipts from the advertisement, the 10 per cent., retained by the Association, being approximately equal to the cost of publishing the advertisement. In other words, the Association places the advertising space of the JOURNAL at the disposal of the Societies, practically without charge, and it remains simply for the Societies to profit by the opportunity.

This reminder has resulted in some increase of activity in this direction. The Engineers' Society of Western New York has secured, for the JOURNAL advertisements on which the Society's commissions amounted to $115.20, which nearly equaled the assessments charged against the Society for the year.

The Cleveland and St. Louis societies continue active in this field, and the Boston Society has also begun taking advantage of this opportunity, but its operations in this direction will not show until the accounts for 1903 are published.

Much greater use might, however, be made of this feature, to the decided advantage, not only of the Association, but also of the Societies themselves. The Journal has a much larger circulation than that of any of the outstanding societies, and it should therefore be easy for each of our Societies to earn, in this way, an amount at least equal to its assessments.

In my report for 1901, I mentioned that arrangements had been made for exchange of advertisements with a number of leading engineering periodicals, under which arrangement notices were inserted in such periodicals, announcing the papers published monthly in our Journal, and that, under this arrangement, our sales of Journals had increased, during 1901, from $182 to $222. A comparison of 1901 with 1902 shows a further increase from $222 to $274, an increase of 19 per cent.

Apart from the direct pecuniary gain arising from this increase, there is of course the indirect gain due to increased acquaintance with our Journal on the part of the engineering profession.

It may be that the slight falling off in the volume of matter, contributed to the Journal by the Societies, during the last two or three years, may be due to the prevailing activity in engineering matters, which leaves the members of our Societies but little time for literary effort, but it is to be hoped that the current year may show an increase in this respect.

Respectfully submitted,

John C. Trautwine, Jr., *Secretary.*

APPENDIX A.

Statement of Receipts and Expenditures during 1902.

CASH, 1902.

Dr.

To Cash Balance, January 1, 1902		$1,368.48	
" Assessments, at $2.00 per member:			
Boston Society of Civil Engineers	$1,011.50		
Civil Engineers' Club of Cleveland	230.00		
Engineers' Club of St. Louis	428.50		
Civil Engineers' Society of St. Paul	26.00		
Engineers' Club of Minneapolis	84.50		
Montana Society of Engineers	193.00		
Technical Society of the Pacific Coast	291.50		
Detroit Engineering Society	222.50		
Engineers' Soc. of Western New York	234.50		
Louisiana Engineering Society	93.50		
		2,815.50	
To Subscriptions	$613.09		
Less amount overpaid, refunded	1.85		
		611.24	
" Sales of Journals	275.76		
Less amount overpaid, refunded	2.00		
		273.76	
" Sales of Descriptive Index		115.00	
" " " Reprints	208.10		
Less amount overpaid, refunded	1.00		
		207.10	
" " " Periodicals		30.60	
" " " Electrotypes		20.32	
" Advertisements		474.00	
" Letter-heads, Engineers' Society of Western New York		2.75	
" Interest on deposits		25.60	
			$5,944.35

Cr.

By Patterson & White Co. (Printers)		$3,022.07
" Illustrations		337.59
" Secretary's salary		600.00
" Expenses of chairman (stationery)		3.18
" Secretary's trip to Boston		23.18
" Commission on subscriptions		39.10
" " " sales		23.84
" " " advertisements:		
Civil Engineers' Club of Cleveland	$61.20	
Engineers' Club of St. Louis	36.00	
Engineers' Society of Western New York	115.20	
N. W. Ayer & Son	1.00	
		213.40
" Binding Vol. XXVII of Journal		1.00
" Messenger service		2.52
Forward		$4,265.88

Brought forward		$4,265.88	
By Telegrams		3.06	
" Express charges		1.90	
" Postage stamps		40.92	
" Stationery		21.51	
" Back numbers bought of Boston Society of Civil Engineers		1.70	
" Allowance, Engineers' Society of Western New York		.70	
			$4,335.67
Cash balance, December 31, 1902:			
Provident Life and Trust Company	$1,523.90		
Cash on hand	84.78		
			1,608.68
			$5,944.35

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1902.

AVAILABLE ASSETS.

Cash balance, December 31, 1902		$1,608.68	
Less subscriptions for 1903, paid during 1902		59.50	
			$1,649.18
Amounts receivable from Societies (for assessments, etc.):			
Civil Engineers' Club of Cleveland	$231.00		
Civil Engineers' Society of St. Paul	25.50		
Engineers' Club of Minneapolis	30.00		
Montana Society of Engineers	67.50		
Technical Society of the Pacific Coast	10.00		
Engineers' Society of Western New York	29.00		
Louisiana Engineering Society	33.00		
		$426.00	
Subscriptions due:			
For 1902	$72.00		
" 1901	42.00		
" 1900 and earlier	309.00		
		$423.00	
For reprints		110.60	
" Advertisements		355.83	
" Sales of Journal		15.90	
" " " Index		5.00	
			$1,336.33
			$2,985.51

LIABILITIES.

Patterson & White Co. (Printers):		
For December Journal	$162.70	
Commissions on advertisements:		
Boston Society of Civil Engineers	90.00	
Civil Engineers' Club of Cleveland	11.25	
Engineers' Club of St. Louis	36.00	
Engineers' Society of Western New York	18.00	
Illustrations	66.37	
		$384.32
Net assets		$2,601.19

APPENDIX C.

Detailed Statement of Gross Cost of Journal during 1902, by Months.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Printer, Sum of 1, 2, 3 and 4.	Illustrations.*	Cost of Manufact'e Sum of 1, 2, 6.	Wrappers.	Sec'y's Salary.	Sundries.†	Total. Sum of 5, 6, 8, 9, 10.	No. of Pages.‡	Cost per Page.‡
January	$259 65	$212 00	$7 30	$15 31	$494 26	....	$471 65	$4 75	$50 00	$23 37	$572 38	180	$3 18
February	73 22	93 50	5 34	7 11	179 17	$5 08	171 80	4 75	50 00	9 48	248 48	72	3 45
March	130 77	157 25	5 08	12 63	305 73	76 13	364 15	4 75	50 00	56 87	493 48	132	3 74
April	60 62	95 75	5 84	7 18	169 39	....	156 37	4 75	50 00	41 04	265 18	76	3 49
May	229 70	105 00	6 30	7 89	348 89	25 50	360 20	4 75	50 00	5 20	434 34	80	5 43
June	90 17	143 65	5 15	11 86	250 83	67 58	301 40	4 75	50 00	8 10	381 26	116	3 29
July	27 75	79 00	4 71	5 90	117 36	3 75	110 50	4 75	50 00	3 45	179 31	48	3 74
August	72 90	138 00	4 53	10 93	226 36	116 76	327 66	4 75	50 00	5 45	403 32	90	4 48
September	45 64	97 25	6 15	5 65	154 69	55 14	198 03	4 75	50 00	14 12	278 70	64	4 35
October	22 57	53 15	5 00	4 29	85 01	19 94	95 66	4 75	50 00	7 16	166 86	38	4 39
November	53 37	89 65	4 75	7 72	155 49	11 48	154 50	4 75	50 00	7 45	229 17	70	3 27
December	49 55	86 75	6 43	7 22	149 95	61 07	197 37	4 75	50 00	8 76	274 53	64	4 29
Totals and averages	$1,115 91	$1,350 95	$66 58	$103 69	$2,637 13	$442 43	$2,909 29	$57 00	$600 00	$190 45	$3,927 01	1030	$3 81

* The figures in column 6 (Illustrations) include preparation of cuts and lithographic stones, and paper and presswork on insets.

† The figures in column 10 (Sundries) include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡ The figures in columns 12 (No. of Pages) and 13 (Cost per Page) include 4 cover pages in each number, and 16 pages in indexes to Vols. XXVIII and XXIX.

APPENDIX D.

Net Cost of Journal, 1902.

Gross cost, as per Appendix C			$3.927.01
Deduct receipts from subscriptions	$611.24		
Less commissions	39.10		
		$572.14	
Sales of Journals	$273.76		
" " Index	115.00		
	$388.76		
Less commissions	23.84		
		364.92	
Sales of reprints	$207.10		
Less cost	142.85		
		64.25	
Sales of periodicals		30.60	
" " electrotypes		20.32	
Advertisements	$474.00		
Less commissions	213.40		
		260.60	
Interest on deposits		25.60	
			1,338.43
Net cost of Journal, 1902			$2.588.58

APPENDIX E.

Statement of Material in Journal during 1902, by Pages.

	Papers.	Proceedings.	Chairman's Report, etc.	Advertisements.	Indexes to Vols.	List of Members.	Totals	Cuts.	Plates and Full-Page Cuts.
January	42	14	12	16		92	176		
February	46	8		14			68	3	1
March	94	20		14			128	26	3
April	56	2		14			72		
May	52	10		14			76	20	
June	84	6		14	8		112	38	1
July	28	1		15			44	19	1
August	70	1		15			86	15	3
September	44	2		14			60	38	
October	16	4		14			34	2	1
November	46	4		16			66		4
December	32	4		16	8		60	11	6
Totals	610	76	12	176	16	92	982	172	20
Covers							48		
Total							1030		

APPENDIX F.

Comparison of the mailing lists of the JOURNAL, at the close of 1901 and 1902, respectively:

	1901.	1902.	In-crease.	De-crease.
Boston Society of Civil Engineers	505	513	8	..
Civil Engineers' Club of Cleveland	231	233	2	..
Engineers' Club of St. Louis	218	215	..	3
Civil Engineers' Society of St. Paul	27	25	..	2
Engineers' Club of Minneapolis	29	61	32	..
Montana Society of Engineers	114	118	4	..
Technical Society of the Pacific Coast	141	150	9	..
Detroit Engineering Society	118	106	..	12
Engineers' Society of Western New York	78	65	..	13
Louisiana Engineering Society	58	58	..	..
Engineers' Club of Cincinnati	78	*	..	78
In the Societies composing the Association	1597	1544	55	108
Net Decrease	**53**			
Extra copies to Societies	47	52	5	..
Advertisers	14	20	6	..
Exchanges	120	133	13	..
Subscribers	224	220	..	4
Complimentary copies	1	1	..	..
	2003	1970	79	112

Besides this, many copies have been sold and specimen pages sent out, and authors of papers have each received five copies of the JOURNAL containing them. Two thousand two hundred and fifty copies of each number have been printed.

*On December 20, 1901, the Secretary of the Engineers' Club of Cincinnati wrote that the Club had decided to withdraw from the Association at the close of 1902; but, inasmuch as this notice failed to comply with the requirement of the Articles of Association that three months' notice of such withdrawal be given, the Cincinnati Club is regarded as not having formally withdrawn from the Association. Pending such action, however, the Secretary of the Association is without revised mail lists for the Cincinnati Club.

APPENDIX G.

COMPARISON OF CONDITIONS, 1894 TO 1902, INCLUSIVE.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
							Pages of Papers.		Gross Cost of JOURNAL.*					Illustrations.			
Year.	Number of Societies in Association, Dec. 31.	Number of Names on Mail Lists of Societies, Dec. 31.	Subscribers, Dec. 31.	Exchanges, Dec. 31.	Net Receipts from Advertisements.	Total Number of Pages in JOURNAL.	Total.	Per 1000 Members on Mail List.	Total.	Per Page.	Per Member.	Per Member per 1000 Pages.	Annual Assessment per Member.	Small Cuts.	Plates and Full-Page Cuts.	Cost.	Net Assets, Dec. 31.
1894	8	1174	176	110	$671 00	1290	653	556	$5774 59	$4 48	$4 92	$3 81	$3 00	86	54	$651 60	—$758 91‡
1895	11	1477	215	122	599 09	1482	792	536	5911 48	3 99	4 00	2 70	3 66	116	66	859 60	223 93
1896	9	1106	241	108	763 25	856	490	443	3928 42	4 59	3 55	4 15	3 00	62	56	771 39	1244 94
1897	10	1252	233	102	410 25	1016	638	510	3140 43	3 09	2 51	2 47	2 50	57	45	503 85	2562 04
1898	12	1370	246	114	465 58	1110	738	539	3462 08	3 12	2 53	2 28	2 00	166	42	729 38	2936 71
1899	11	1475	249	115	390 88	958	544	369	3233 44	3 38	2 19	2 29	2 00†	124	30	561 24	2442 70†
1900	11	1541	216	116	370 83	1130	666	432	4351 53	3 85	2 82	2 50	2 00	112	27	590 82	2162 67
1901	11	1597	224	115	244 10§	1074	646	405	4856 64	4 52	3 04	2 83	2 00	213	55	1160 90	2062 72
1902	11	1544	220	135	260 60	1030	610	395	3927 01	3 81	2 54	2 36	2 00	172	20	442 43	2601 19

* The publication of the Descriptive Index of Current Technical Literature was discontinued at the end of 1895.

† During 1899, with an assessment of $2.00 per member, the Association made a rebate of $1.00 per member for the purpose of reducing surplus, making the actual charge only $1.00 per member, and reducing the assessment by about $1400.

‡ Deficit at close of 1894. Since then, each year has shown a surplus.

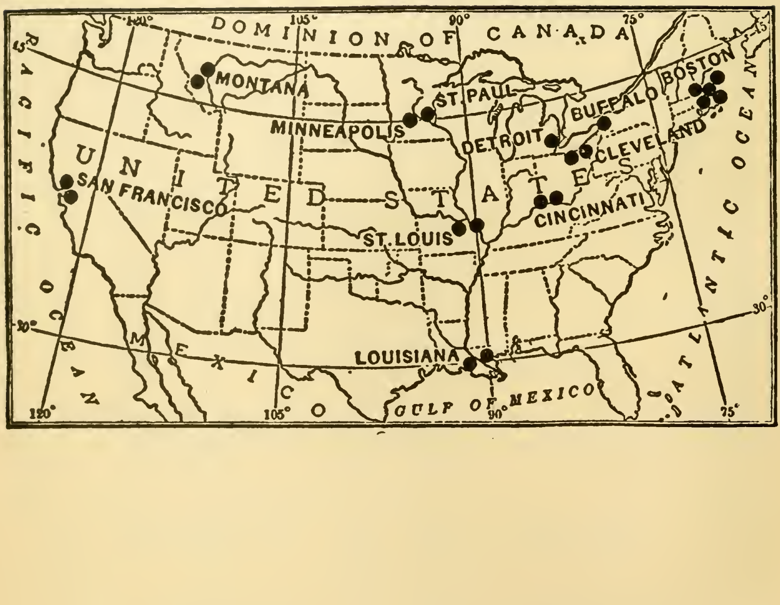
§ In Appendix F, for 1894–1901, as printed in the JOURNAL for January, 1902, the gross receipts, $331.50, were given, by oversight, instead of the net receipts, $244.10.

APPENDIX H.

Comparison of Conditions, 1900, 1901, 1902.

December 31st.	Members on Mail List.	Total Pages in Journal.	Printers' Bills.	Cost of Illustrations.	Manufacture.	Gross Cost of Journal. Total.	Gross Cost of Journal. Per Page.	Gross Cost of Journal. Per Member.	Gross Cost of Journal. Per Member per 1000 Pages.	Net Cost of Journal. Total.	Net Cost of Journal. Per Page.	Net Cost of Journal. Per Member.	Per Member per 1000 Pages.	Net Assets.
	Col. 2, App. G.	Col. 6, App. G.	Col. 5, App. C.	Col. 16, App. G.	Col. 7, App. C.	Col. 9, App. G.	Col. 10, App. G.	Col. 11, App. G.	Col. 12, App. G.	App. D.				Col. 17, App. G.
1900	1541	1130	$2803.77	$590.82	$3218.44	$4351.53	$3.85	$2.82	$2.50	......	......	......	......	......
Increase	56	......	......	570.08	380.57	505.11	0.67	0.22	0.33	......	......	......	......	......
Decrease	......	56	69 03	......	......	......	......	......	......	......	......	......	......	$99.95
Per Cent.	3.6	5.0	2.5	96	12	12	17	7.8	13	......	......	......	......	4.6
1901	1597	1074	$2734.74	$1160.90	$3599.01	$4856.64	$4.52	$3.04	$2.83	$3311.60*	$3.08	$2.07	$1.92	$2062.72
Increase	......	......	......	......	......	......	......	......	......	......	......	......	......	538.47
Decrease	53	44	$97.61	$718.47	$689.72	$929.63	$0.71	$0.50	$0.47	$723.02	$0.57	$0 39	$0.29	......
Per Cent.	3.3	4.1	3.6	62	19	19	16	16	17	22	17	19	15	21
1902	1544	1030	$2637.13	$442.43	$2909.29	$3927.01	$3.81	$2.54	$2.36	$2588.58	$2.51	$1.68	$1.63	$2601.19

* See Journal, Vol. XXVIII, No. 1, page 48, January, 1902.



DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
UNITED STATES
CINCINNATI
ST. LOUIS
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
LOUISIANA
GULF OF MEXICO

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXX. FEBRUARY, 1903. NO. 2.

THE THEORY OF OPERATION OF THE GASOLINE ENGINE.

BY E. C. OLIVER, M.E.

[Read before the Engineers' Club of Minneapolis, December 18, 1902.*]

IN the discussion of a subject of this kind it is a little difficult to choose just what to say, unless one is acquainted with the interests of those to whom he addresses himself. While the first attempts at building an explosive engine date back about one hundred years, yet it has been within comparatively recent years that the really important part of the work of perfecting this type of motor has been done.

Within the last fifteen or twenty years there has been activity among engineers and scientists with regard to this style of heat engine, the one perfecting the mechanical details, the other supplying the theory adapted to the new requirements, and still at this day we see and realize the comparative meagerness of the data available for the gas engineer.

The gas or gasoline engine is primarily a heat engine; and the heat-engine laws, or, in other words, the laws of thermodynamics, are the ones on which we must base our theory. We might make the general statement that anyone who has to do with the design of gas or gasoline engines must base his design on these thermodynamic principles or on someone else's design, which was in turn based on the proper laws.

It will be necessary, then, to treat the subject from this standpoint; yet we will endeavor to confine ourselves to the elementary principles of thermodynamics only and not indulge in the more complex considerations, without which, I think, a fair understanding of the subject may be had.

*Manuscript received February 23, 1903.—Secretary, Ass'n of Eng. Socs.

We know that in a pound of fuel, be it coal, wood, kerosene, gasoline or gas, there is a definite amount of latent energy which, when the substance is burned, is liberated and takes the form of heat. Thus we say that a pound of coal contains a given number of heat units, which means that, when the fuel is burned, the heat evolved can be measured by some definite scale. The unit which has been agreed upon is that amount of heat which will raise the temperature of one pound of water one degree Fahrenheit, and if you think of that for a moment you will see that it is quite a sensible amount, and not one of the infinitesimal quantities with which we sometimes deal in theory. This amount of heat is called a British thermal unit, or, as it is generally designated, a B. T. U.

It has also been determined that this amount of heat may be represented by a definite amount of useful work; that is, by very careful and exact experiments it is found that, if 778 foot-pounds of work are performed on 1 pound of water, its temperature is raised 1 degree, the same effect that the addition of 1 B. T. U. would have on the water. Then we say that 1 B. T. U. is equal to 778 foot-pounds of work.

However true this statement is, the converse has never been attained; that is, 778 foot-pounds of useful work have never been obtained by the expenditure of 1 B. T. U., and the great heat-engine problem, which has been confronting engineers from the time when we first obtained power from fuel, is, how to convert heat units into mechanical energy with the greatest possible efficiency; that is, how to make the number of foot-pounds of work derived from each B. T. U. approach 778 as nearly as possible. There seems to be some sort of a ratchet arrangement in the system which hinders the rule from operating equally well both ways.

The most common method of accomplishing the conversion of heat into work, and the one with which we are most familiar, is to burn the fuel in a furnace under a boiler partially filled with water. The water absorbs part of the heat and changes into steam under pressure. This steam is then used in an engine to move a piston back and forth, which piston is connected by means of suitable mechanisms to the work to be done. In the steam engine the whole operation is a series of losses. First, the entire heat of the fuel is not absorbed by the water in the boiler. Second, the greater amount of the heat absorbed by the water is used in supplying the latent heat of evaporation, and this is still in the steam when it is exhausted; hence is not available for doing work. There are also losses due to radiation, condensation, leakage, etc., all of which

tend to bring the efficiency of a steam engine, as a heat engine, down to a surprisingly low figure.

The best steam plants, when taken as a whole, and including furnace, boiler and engine, as machines for converting heat into mechanical energy, have an efficiency less than 10 per cent.; and this refers to engines which use but 11 pounds of water per indicated horse power per hour, the lowest rate which has been attained up to the present time. When it is considered that engines of ordinary size, 100 to 200 horse power, working under ordinary conditions, use 20 to 25 pounds of water per indicated horse power per hour, and that common engines use as high as 70 to 100 pounds of water per indicated horse power per hour, we see something of the desirability of improving on this efficiency.

A great number of devices have been suggested and put into operation to increase this efficiency, and with more or less success; but by far the most important device which has been used or suggested for raising the efficiency of heat engines is to employ an entirely different system; to do away with all accessories and to use the fuel right behind the point of application of the load; and this method, though still imperfect, is, under certain conditions, very much superior to that of the steam engine.

This method can be used to greatest advantage where we have a supply of the more inflammable fuels, such as kerosene, gasoline or gas. Outside apparatus is necessary to make use of the heavier oils and the solid fuels, as any of these must first be converted into one of the three mentioned before it can be made available, and the engines which use this form of fuel are known as oil, gasoline or gas engines. The methods employed in each are somewhat similar.

This manner of converting the latent heat energy of fuel into useful work through the medium of the gas engine has brought out many various forms of engines, much the same in general principles, yet varying in many details.

The detail of greatest importance is that concerning the cycle of operation, and this detail divides the engines into two general classes, (1) those operating with the two-stroke cycle and (2) those operating with the four-stroke cycle. There have been some other styles, but these two are the most important, and nearly all of the present-day engines follow one or the other of these styles.

Regarding the adaptability of the gasoline engine to various purposes, it is useless to make any statement, because I have not in mind any use to which a steam engine of moderate size may be put for which a gas engine may not also be equally well employed,

and, indeed, sometimes with considerable advantage. Most of us are familiar now with seeing gasoline engines used for all stationary purposes, and in automobiles and pleasure launches, but other uses probably not so familiar are powerful harbor tugs, such as are used on the Pacific coast, equipped with gasoline engines; their use also in all manner of contractors' sets, such as cement mixers, hoisting machines and air compressors, such as are used for operating pneumatic tools when erecting bridges, tanks and other structural iron work in the field. Traction and threshing engines are now operated by gasoline, and even the festive flying machine. The great amount of fuel, with reference to work done, which can be stored in a small space and the ease with which the whole machine may he handled and transported are some of the important considerations in the cases above named.

It is true that at one time the gas engine had an undesirable reputation as to reliability. It was generally thought that the engine would go sometimes, but if you wanted your machine or shop to run, it was well to have some other source of power available to take the place of the gas engine when it had a "fit." There may have been some ground for this reputation, but probably the trouble was due more to the operator than to the engine. With the present engine this idea has almost entirely disappeared; people are getting educated to the use of the engines; there is less mystery about them, and the people who are building them also understand the engine better, so that good design and workmanship have done much to improve the impaired reputation.

Indeed, in many towns gasoline engines are depended on for the water supply, and are used as a reserve in case of fire, because of their prompt starting qualities.

We have said that there are two general styles of gas and gasoline engines, the two-stroke cycle engine and the four-stroke cycle or Beau de Rochas cycle, commonly, though improperly, called the "Otto" cycle engine.

Until a short time ago, the two-cycle engine was used almost entirely for small engines for marine purposes, in sizes up to 6 or 8 horse power per cylinder.

In the last few years, however, a number of exceptionally large engines have been built to use blast-furnace gas for fuel and to operate blowing engines. Engines of this kind have been built which generate 2000 horse power. They usually have two or four cylinders, and are double-acting two-cycle engines, yet working on a system somewhat different from that of the ordinary two-cycle engine.

These engines are provided with separate pumping cylinders, in which the charge is previously compressed and fed to the large cylinders at the proper time and in the proper proportions.

We will confine ourselves, however, to the type of two-cycle engines with which we are most familiar, that type in which the charge is previously compressed in the crank case.

The principles of operation of a two-cycle engine may be shown by reference to Fig. 1. This engine consists of a cylinder,

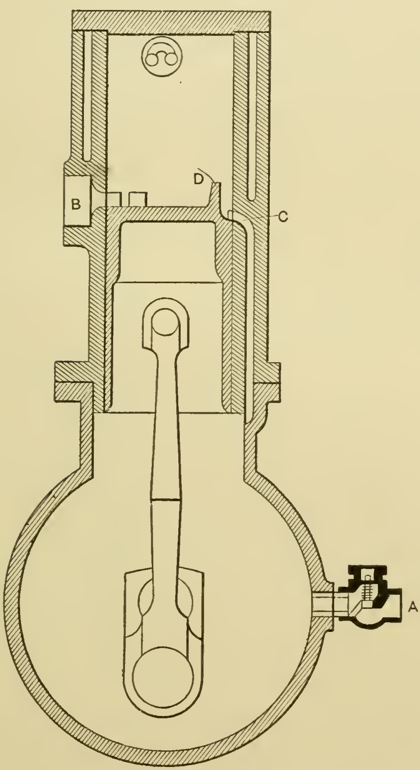


FIG. 1.

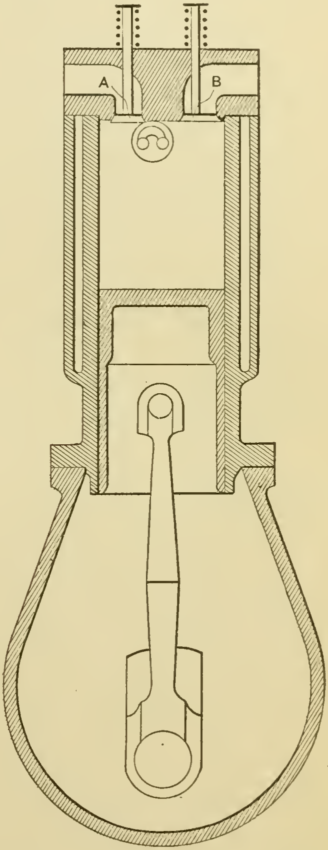


FIG. 2.

piston, connecting rod and crank case, with the necessary passages, valves, etc.

The various phases in the operation of this cycle take place partly on one side of the piston and partly on the other. Let us first follow through what happens below the piston in the crank case.

This crank case is made as nearly air-tight as possible, and has, at A, a check valve opening inward. Now, with the piston at the bottom of the stroke and starting upward, it is obvious that the volume in the crank case is increasing, and that air, or air and gasoline, as the case may be, will be drawn in through the check valve to keep the pressure up to atmospheric, and that, as the piston reaches the top of the stroke and returns, the check valve will close and the gases which are contained in the crank case will be compressed, the amount of this compression depending on the relation of the volume of the crank case to the piston displacement.

When the piston is at or near the bottom of the stroke, a part of the charge of gas below the piston is transferred to the space above the piston, which has been emptied of the exhaust gas; and on the next up-stroke this charge is compressed a second time and to a much greater extent than before, the upward motion of the piston at the same time drawing a fresh supply into the crank chamber. A little before the piston has reached the top center, the charge is ignited by means of an electric spark or other means, and through this ignition the heat of combustion of the fuel is liberated and the gas within the cylinder is greatly expanded; or, if the expansion cannot take place, that is, if the combustion is at constant volume, the pressure is increased.

This increase of pressure acts on the piston and forces it down and, by means of the connecting rod, causes the crank to revolve and work to be done. As the crank nears the bottom center, we evidently cannot get much more work out of the heated gas, so we have an opening, B, through the cylinder wall, which is uncovered by the downward motion of the piston, and the heated gases immediately rush out through this opening, relieving the pressure on the piston. A slightly greater advance of the piston uncovers another port, C, on the opposite side of the cylinder, which communicates with the crank case, and the charge of fresh gas, which we have seen already compressed at each descent of the piston, rushes into the space previously occupied by the burned gas. The piston has a sort of fence or deflector, D, immediately in front of the induction port, to prevent the fresh gas from rushing over the piston and out of the exhaust port. Instead, it is thrown upward and displaces more of the burned gas, and this part finds its way out of the exhaust, leaving the space above the cylinder filled with fresh gas, to be compressed and ignited on the return to the piston. To what extent the old gas is forced out and the new gas retained depends to a great extent on the design of the engine.

Thus the operation of the two-cycle engine proceeds, drawing in its supply of carburetted air to the crank chamber, compressing it slightly, transferring it to the upper part of the cylinder, compressing again, igniting, expanding and exhausting.

The great difference between this and the action of the four-cycle engine is that, in the latter, all the operations or phases of the cycle take place on one side of the piston and each phase occupies one stroke of the piston.

Fig. 2 illustrates a four-cycle engine. Its operation is as follows, commencing with the suction stroke:

Here the piston is at the upper end of the cylinder, moving downward. A partial vacuum is formed in the cylinder, and air charged with gas or vaporized gasoline enters through valve A. This continues till the end of the stroke, called the induction stroke, when the valve closes and the charge is compressed by the return to the piston. This is called the compression stroke. When the piston is about to pass the upper center, the charge is ignited, the pressure increases and the piston is forced downward. This stroke is called the expansion or power stroke. When the piston is near the end of the cylinder, valve B opens and the gas rushes out or is forced out on the back stroke of the piston, and this is called the exhaust stroke. Thus we have the cycle complete in four strokes of the piston.

This type of engine is made in sizes from the smallest up to 200 to 300 horse power, and is by far the best known and most popular type. It is used almost entirely in automobiles.

Now, it will be noticed that, in each of these cycles, the same things occur: first suction, then compression, next explosion and expansion, and last, exhaust; the choice between the two systems being made by a comparison of the cheapness and more constant torque of the two-cycle with the better economy and, some would say, the greater reliability of the four-cycle.

These cycles may also be compared by means of their indicator diagrams, and, in fact, this is the satisfactory manner of ascertaining what happens in any engine cylinder, be it for gas, steam or water.

An indicator diagram is not, as generally supposed, difficult to understand. A diagram is only a graphical record of the pressures within the cylinder during a revolution or a cycle, and as such it is easy to understand. However, from this simple record of pressures may be drawn many very interesting deductions, which require a knowledge of the laws of the curves and some other data.

In Fig. 3 we have a representative diagram, or diagrams, from a two-cycle engine. Since we have seen that the cycle is performed partly on each side of the piston, we must have a diagram from each side.

The right-hand diagram is the diagram from the crank case. You will notice the lower line is slightly below and parallel with the atmospheric line. This signifies that it requires a slight difference of pressure to cause the air from the atmosphere to flow into the crank case, and at the end of the stroke the crank chamber is full of air at this pressure. Now, as the piston returns, this air is entrapped and compressed along the line 1, 2 until the induction port is uncovered at 2, when it rushes to the top of the cylinder; and, as the piston returns, the air that is left in the crank case expands until the pressure falls enough to admit fresh air from outside, as indicated at 3.

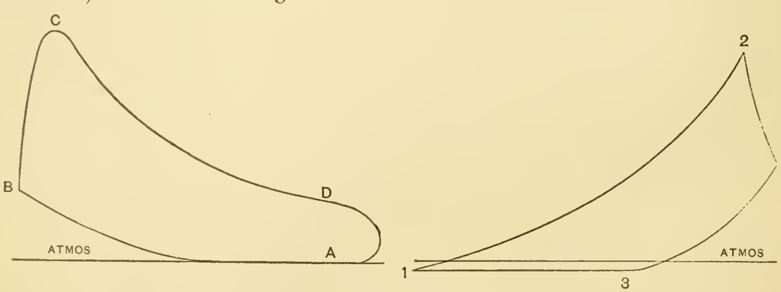


Fig. 3.

On the other side of the piston (left-hand diagram), after the air has been transferred it fills the cylinder at atmospheric pressure, as indicated at A. As the piston advances, the pressure rises higher and higher, till the piston reaches the end of its stroke at B, when it is ignited, the pressure increases to C, and, as the piston moves toward the crank under the pressure thus produced, the gas expands and loses pressure until the exhaust port is uncovered at D, when there is a rapid drop to the pressure of the incoming new charge.

In the four-cycle diagram, Fig. 4, there are two divisions of the card, but these are somewhat different from those in Fig. 3. Starting with admission, shown on the diagram at A, the pressure is seen to drop until it is sufficiently low to allow the air to flow into the cylinder. This continues throughout one stroke. The admitted air is then compressed along the curve B, C; ignition occurs, the pressure rises to D, and expansion occurs throughout another stroke. Near the end of this stroke, at E, the exhaust valve is opened and the pressure falls to slightly above atmo-

spheric. This pressure indicates the amount required to force the air through the exhaust valve into the atmosphere. Then commences another suction stroke, and so on.

In either engine the most important part of the cycle is, of course, the expansion or explosion stroke; all else is supplementary to this, and we will follow this stroke through more carefully; but, before considering it, I want to mention a few of the accessories upon which depend the proper operation of the engine, and which have not to do with the cycle. These accessories are the carburettor, the governor and the ignition device.

The time at my disposal will not permit of going into these details fully enough to explain their operation. It will be sufficient to say that three kinds of carburettors are used, (1) those which inject into the incoming air a measured amount of gasoline, (2) those in which the air flows through or over the gasoline and is

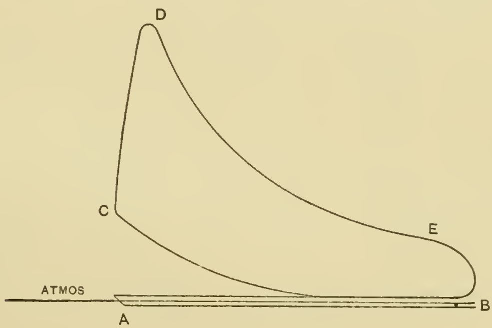


FIG. 4.

thereby charged with the fuel, and (3) those in which the fuel is drawn from a constant level supply tank by the suction of the incoming air and, passing through various wire screens or other devices, is vaporized and mixed with the air.

The governor arrangement is made to act in one of three different ways, (1) by missing explosions when the speed is above normal, (2) by throttling the mixture, and (3) by changing the lead of the spark. With the first method the explosions are approximately of the same intensity. In the second and third the mean effective pressure of each stroke is varied. A greater efficiency is claimed for the "hit-and-miss" method, and better regulation for the throttling method. The third method is of little value, because of its lack of efficiency, and is very seldom used.

Ignition also is accomplished by one of three methods. The method in use till a short time ago was by means of a hot tube in communication with the combustion space of the engine. This

gives good results, but does not allow of changing the lead as easily as others. The make-and-break spark system employs a low-tension electric current, and has given good results on constant speed engines. The jump spark or high-tension igniter is used now almost to the exclusion of others for variable speed engines. The first has been used in connection with the last method in some particular cases.

By using various combinations of these methods we are able to get a considerable number of different types of engines. Each maker has his choice among them, usually determined by experience and experiment.

There are, however, very few "different" engines as regards the theory of operation. Once in a while someone brings out something promising, but we have still to see anything very different from the four-cycle engine.

Returning now to the particular part of the cycle before mentioned, we know that at the beginning of the compression stroke we have in our cylinder an amount of fresh air, gasoline—gas and burned gas which are mixed together and compressed to a definite pressure as shown by the indicator diagram. The amount of this pressure is a function of the compression space; as the space becomes smaller the pressure is higher, and this rise of pressure is accompanied by a corresponding rise of temperature.

Upon the relation of these various quantities, viz: the temperature, the pressure and the volume of the mixture at the point of ignition, depends to a great extent the ultimate efficiency of the engine.

For any gas or for any mixture of gases there is a definite law which defines the relation of temperature, pressure and volume. This law takes the form $PV = RT$, in which P is the pressure in pounds per square foot, V the volume in cubic feet, R a constant depending on the nature of the gas and T the temperature in Fahrenheit degrees measured from absolute zero or 461 degrees below the zero of the Fahrenheit scale. With these units the law states the relation for one pound of the gas.

This law holds for any point in the cycle of our gasoline engine, whether in the expansion or compression curve. Therefore, if we know the pressure, temperature and volume of the gas at any point, as at the beginning of the compression stroke, we may compare these quantities for any other point in the cycle from the data derived from an ordinary indicator diagram.

On the other hand, we are able to lay out approximately the curves of compression and expansion as we will find them, if

we know the relative volumes and properties of the gases. Thus, if we start with the commencement of the compression stroke, a place for which we may know the temperature, pressure and volume, and from this point compress the gases within the cylinder in such a way that the water jacket is enabled to carry away the excess of heat caused by the compression, so that the temperature may remain constant, our relation $PV = RT$ still holds; but, since R is a constant, and since, in this case, T is a constant also, our relation may be stated $PV = C$, and this is known as the isothermal expansion (or compression) curve.

If, however, there is no transfer of heat to the cylinder walls, so that, at the end of the stroke, the gas contains all of the original heat plus the amount added by the work of compression, the compression (or expansion) is said to be adiabatic, and the same law, connecting pressure, volume and temperature, obtains. This law may be altered in form to correspond with the isothermal law stated above, and when so altered takes the form $PV^{1.41} = C$.

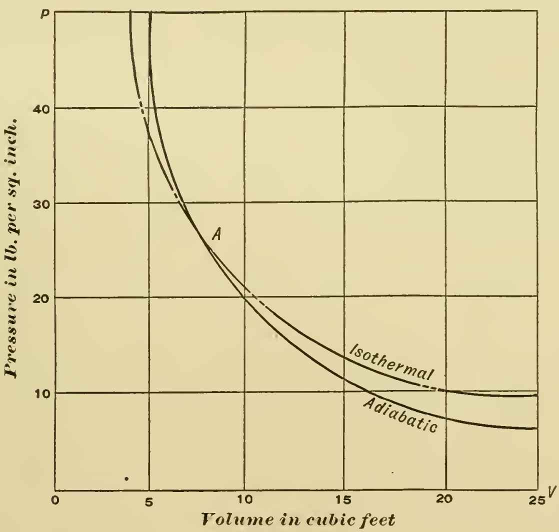


FIG. 5.

For the sake of comparison, these curves are shown in Fig. 5. The adiabatic is much steeper than the isothermal, as is clearly shown by the equation.

In practice, however, we have neither one of the foregoing conditions. There is some interchange of heat to and from the cylinder walls; not enough to make the operation isothermal and still enough to prevent it from being purely adiabatic. So the actual compression and expansion curves lie between these two

extremes, the effect on the equation being to lower the exponent from 1.41 to about 1.3. Hence a fair idea of the relation and volume may be had from the equation $PV^{1.3} = C$.

With this relation we may compute the required clearance for a desired pressure of comparison; or, with a given clearance, we may compute the probable pressure of compression.

What we have said concerning the laws of compression is true for any mixture of gasoline—gas and air; but we know that any mixture, at random, will not give us the results we wish. If the proportions of gas and air are correct, or within certain limitations, the combustion will be complete, but, if the fuel is in excess, there will be some unburned products in the exhaust, and the explosion will not be so energetic; while, if the air is in excess, the charge will give a weak explosion. In fact, it is possible to have the gas either so weak or so strong that it will not explode at all, and these limits are not so very far removed from those proportions which are just right.

Knowing, then, the amount of fuel used per explosion, and assuming that the combustion has been complete, we are able to compute the exact number of B. T. U. liberated per cycle.

At the moment of explosion there is a marked transformation taking place in the nature of the gas within the cylinder, and that amount of mixture of burned gas, gasoline gas and fresh air which existed just before ignition is changed to a mixture of nitrogen, carbon dioxide and steam or water vapor; and the properties of this gas are somewhat different from what they were before. Also, there has been liberated a definite number of B. T. U. as a consequence of this combustion or change, and the effect of this liberation of heat units is to raise the temperature of the burned gas. All of this happens in an extremely short space of time.

This burning takes place at constant volume, and, as the gases have a definite specific heat, the same as water or any other substance, if there were no outside influence to add or extract heat the rise in temperature might be computed, and this rise in temperature would have its proportional rise of pressure, by virtue of which the piston would be pushed forward and work done.

As the piston proceeds the pressure must fall, because of the increasing volume. In fact, conditions are the very opposite of those which obtained during the compression, and we have the same law applying. By means of our adiabatic equation we could compute, with a fair degree of accuracy, the path of the pressure as it would be shown on the indicator diagram if there was no cooling effect of the cylinder walls.

Provided this condition did obtain, that no heat were lost outside of the cylinder, if we computed the heat units existing in the gas at the end of the stroke, we would find that we had as many as at the beginning, less that number which has been transformed into work by moving ahead the piston. This is another statement of the law of adiabatic expansion, already mentioned.

There are, however, some conditions which interfere with this result. The exceedingly high temperature of the burned gas affects the cylinder walls to such an extent that it is necessary to have a water jacket surrounding them in order to keep the walls cool enough to hold the lubricant. The water flowing through this jacket is continually absorbing heat from the walls, and the walls are absorbing just as much from the gases. So, as the cycle proceeds, we see our liberated heat units becoming dissipated. Part are transformed into work by virtue of the moving piston, and part are being absorbed by the water jacket.

The effect of the water jacket is to lower the expansion line of the diagram. The cooler the jacket, the lower the line and the less the mean effective pressure. But there is another and more marked effect of the water jacket, and this takes place during combustion, cutting the top entirely off of the diagram, and giving us a lower maximum explosion pressure than would have been computed according to the laws mentioned, so that the expansion curve is more nearly horizontal than the theoretical, instead of being more nearly vertical, as would be expected. The reason for this is that the entire curve lies inside of the theoretical curve, and the mean effective pressure is, of course, much less for any definite explosive mixture.

The relation between the pressure of compression and the maximum explosion pressure therefore depends to some extent on the temperature of the water jacket, and much experimental work has been done in order to formulate a rule by which this relation could be stated for practical purposes, so that curves are now available by means of which we may determine approximately the pressure of explosion which we may expect from a given pressure of compression.

While engaged in the mechanical engineering laboratory of the University of Illinois the writer was interested in studying the distribution of heat and the range of temperature in a gasoline engine, and made a series of very careful tests for the purpose of determining just what happened.

These tests were made on a 10 horse-power "Otto" gasoline engine and were of about 20 minutes' duration, and all quantities

which in any way affected the results were directly measured. These quantities included weight of air, weight of gasoline, heat given off to water jacket, heat given off to exhaust, brake horse power, indicated horse power, etc. Samples of gasoline and burned gas were analyzed and all precautions were used to insure accurate results.

Space will not permit of the details of methods or computations in regard to these tests, but the data and results have been added in tabular form, as it is thought they may be useful for reference or comparison.

TEST OF 10 HORSE-POWER OTTO ENGINE.

Engine cylinder 5¾ inches diameter, 12½ inches stroke.
Clearance 107 cubic inches.
Duration of tests 22¼ minutes.
Brake load 8.988 horse power.
Revolutions per minute 299.6.
Total number of explosions 3332.
Weight of gasoline used 2.43 pounds.
Weight of air used 42.67 pounds.
Weight of jacket water 361 pounds.
Rise of temperature of jacket water 47.4 degrees F.
Weight of exhaust cooling water 382 pounds.
Rise of temperature of exhaust cooling water 37 degrees F.
Indicated horse power 10.75.
Friction horse power 1.762.

From these data there was a heat balance made out for the engine, charging it with the amount of heat delivered to it in the form of gasoline, and crediting the various amounts of heat as determined by the tests.

HEAT BALANCE OF 10 HORSE-POWER OTTO GASOLINE ENGINE.

	Dr.	Cr.
2.43 pounds gasoline at 18,281 B. T. U.	44,423	....
9.988 B. H. P. for 22¼ minutes	....	8,483
1.762 F. H. P. for 22¼ minutes	....	1,663
361 pounds jacket water at 47.4 degrees	....	17,111
382 pounds exhaust cooling water at 37 degrees	....	14,134
Heat rejected in exhaust gas	....	371
Total heat directly measured	....	41,762
Radiation and other losses	....	2,661
	44,423	44,423

In percentages of the total heat supplied this balance would stand as follows:

	Per cent.	Per cent.
Total heat supplied to engine	100	....
Brake horse power	...	19.10
Friction horse power	...	3.70

Jacket water	...	38.50
Exhaust	...	32.70
Radiation	...	6.00
	100	100.00

The thermal efficiency of the engine is the sum of the first and second entries in the foregoing table, or 22.8 per cent.

The temperatures at various parts of the cycle, as obtained by direct computation, are as follows: At explosion, 2800° F.; at release, 2040° F.; exhaust at atmospheric pressure, 1006° F., and at compression, 490° F.

THE METRIC SYSTEM.

By C. H. Tutton, Member Engineers' Society of Western New York.

[Read before the annual meeting of the Engineers' Society of Western New York, December 2, 1902.*]

The following is a copy of a circular sent out by our retiring President:

There is a Bill, viz., H. R. 123, now on the Calendar of the House of Representatives of the Congress of the United States, entitled:

"A bill to adopt the weights and measures of the metric system as the standard weights and measures in the United States."

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that on and after the first day of January, nineteen hundred and four, all the Departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, nineteen hundred and seven, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States."

This bill has been reported favorably by the Committee on Coinage, Weights and Measures, and it is said that its friends intend to urge its passage at the coming session of Congress.

The members of Congress from Western New York have signified a desire to learn the opinions of engineers and other "practical men" about the desirability of the passage of this bill in its present form at the present time.

The matter was brought to the attention of the Society last spring, and again at the October and November meetings. At the latter it was referred to the members attending the annual meeting, and the Secretary was directed to bring it to the attention of each person connected with our Society, so that they could come to the annual meeting prepared to express their opinions.

It will be noted, by reading the bill, that it is intended to change the entire system of weights and measures of the United States—a compulsory measure making the metric system the only legal standard of the country on and after January 1, 1907—a change affecting every man, woman and child much more than any tariff, and they intend to do this without any notification whatever to the people of the United States, or discussion by them.

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*Manuscript received January 15, 1903.—Secretary, Ass'n of Eng. Socs.

We hope that you will be prepared to express your opinion on this matter at the annual meeting.

W. A. Haven, *President.*

The foregoing circular explains the appearance of this paper. The support of the House Committee seems to have been obtained by misrepresentation and misstatement of facts on the part of the adherents of the bill, for the true issue involved is not academic.

The Western Society of Engineers of Chicago recently had a discussion upon this subject and sent out 421 letter ballots. 153 replies were received, showing 130 votes for and 23 against the system.

The Committee of the Franklin Institute has also reported in its favor.

What is known as the metric system has been defined as "the national characteristic of the only nationality that ever officially denied the Divine existence." It was born amid the riot and disorder of the French revolution in 1795, coincident with the attempt to abolish the Christian religion by legislation, and made compulsory by the same means at the same time. Notwithstanding this, it was not until 1840 that it could be said in any sense that it was adopted, and to-day, on the eve of 1902, the old French inch (système ancien) is still in legal use in France.

The length of the meter, owing to error in the determination of the meridional arc, is arbitrary, and the accurate length of the bar representing it had not been determined, according to various authorities, until about 1889.

We have the determinations of Kater, Hassler, Bailey, Comstock, Rogers and Clarke (the determination of Clarke being used by the United States Coast and Geodetic survey), the so-called Committee Meter, and last, but not least, we have the United States law, which establishes its length as something which agrees with none of them.

At the annual meeting of the American Society of Mechanical Engineers, now being held in New York city, Mr. F. A. Halsey, Associate Editor of the *American Machinist,* will present a paper on this subject, from an advance copy of which free extracts will be made in the following. Detailed facts, figures and references will be found in his paper, which will more than repay perusal.

If legislation, compulsory though it be, meant adoption, which the advocates of the system assume, they might have some ground for argument. As facts, we find:

That to-day, after 28 years of compulsory legislation, enforced by fines, the old German units persist in that country in all textile industries, and in very many mechanical industries, and the English system of pitch threads is universal. The carpenters and other building mechanics nearly universally use the old Rhenish inch (1.0297 English inches), and rules graduated in Rhenish and English, and sometimes French inches are purchasable in every hardware store in Germany.

That to-day, after 107 years of compulsory legislation, the old French pouce or inch (1.06576 English inches) is the standard in France in all textile industries, national pride and despotic government combined not having succeeded in eradicating it, and the same condition of affairs obtains in Italy, in Switzerland and in Austria.

And to-day, after 18 years of compulsory legislation, it is the common practice in Mexico to use American measurements for all railroad machinery, while in South or Spanish America, nearly every country of which is nominally metric, their old measures are still in common use. A list of 47 of these measures may be found in the monthly bulletin of the International Bureau of American Republics, issued at Washington, D. C., for October, 1902, and also in many of the consular reports.

Every country in the world, without any exception whatever, still measures gems by the carat.

As to argument on foreign trade, the National Machine Tool Builders' Association condemned the measure at their Cleveland convention, October, 1902, for reasons which may be found in their proceedings and in Mr. Halsey's paper.

Mr. Andrew Carnegie, in his inaugural address as rector of St. Andrew's University in Scotland, said:

"America now makes more steel than all the rest of the world. In iron and coal her production is greatest, and it is also so in textiles. She produces three-quarters of the world's cotton. The value of her manufactures is about triple that of your own. Her exports are greater, and the clearing house exchanges at New York are almost double those of London."

To what do we owe our national supremacy? The question being asked of Queen Victoria, relative to that of England, she handed the questioner a Bible.

Every coin of our nation bears the motto "In God we Trust." Many weigh the name on scales that deny Him, but we further propose to perpetuate what we owe to Christianity, by adopting for a national standard of weights and measures, which will be carried

into the daily life of each individual of our nation, "the national characteristic of the only nationality that ever officially denied the Divine existence." Shall the mountain go to Mohammed at last? I apologize to one of our members present for stealing a little of his thunder, but cannot here refrain from asking, What has posterity done for us that we should do this for posterity?

In the report of the Committee on Coinage, Weights and Measures of the House of Representatives occurs the following:

"The practical applications of scientific work have in many cases been seriously handicapped or retarded, owing to the necessity of converting formulæ derived in the metric system to equivalent formulæ in the common system."

Are we to suppose, then, that the reverse process is easier? Is it so much simpler to transform the thousands of existing English formulæ to metric measures that this change is desirable? Do men of the caliber implied by this reason call themselves scientists? Is it a fact that our scientists, and those capable of applying science, are so highly educated that they are unable to transform a formula, and would sooner sacrifice our industrial welfare than attempt it? If so, if scientists are unable to cope with the metric system, what about the millions of our everyday people who do not profess to be such?

Again, the report of the committee says: "It should be emphasized that this measure in no way contemplates any change in any existing technical standards, such as screw-threads, wire gauges, lumber measures and numerous others, except as manufacturers and other interests find it to their own interest to make the change."

This is a plain misrepresentation of facts, for the law does not read that way. "Shall" does not imply permissiveness, but if it be susceptible of such interpretation, it is the worst piece of legislation that ever appeared upon our country's statute books. It adds a new, without wiping out the old system, and the people at large must necessarily bear the burden, pay for the change, and then—learn both systems. To-day the double system is used by comparatively few, and these few presumably able to cope with it; then, the double system will be general and all must learn it. To build a house we must measure the area of its floors in the metric system, and lay them with boards cut on the English system; must describe our door hinges by metric measures and buy screws to fasten them on with by English measures and so on through the list. And such a system is recommended for its simplicity.

If, by the terms of this bill, the Government is to use this system in all its transactions, and if the above report by the House Committee be construed as an interpretation of the law, the Government will go without many kinds of machinery altogether.

Again, the exception made by the bill relative to surveys of the United States public lands perpetuates our present system, while in the very same breath no action in law can be maintained except in measures based on the metric one.

Mr. Halsey says, "All knowledge is comparative, and comparison is impossible except through the use of weights and measures."

In a letter of the Brown & Sharpe Manufacturing Company to the House Committee, its writer says, "The question of weights deals rather with the future, but . . . linear measures are tied irrevocably to the past."

This should be emblazoned upon the walls of the halls of Congress and upon those of the rooms of its committee. Suppose it is true that the benefit and ease of calculation, arising from the use of the decimal system, be almost limitless in extent, as claimed by many calling themselves scientists, it still remains that every experiment that ever has been made, every result that ever has been obtained, stands to-day in the original measures; they are tied irrevocably to the past. If the couple of dozen, or couple of hundred even, of scientists in Buffalo, for example, are too indolent to transform to the present system the few experiments in foreign measures which they—and in all probability they alone—desire to use, is that any reason why the remaining 400,000 people here should be compelled to change their whole system of education, almost their being, in order to set a premium on—well, it is nothing but laziness and may as well be called by that name.

Suppose that the labors of engineers and scientists generally were lightened by the use of this system, what would it amount to? What is their proportion to the public at large, and why should the labor of a few men here and there be lessened at the expense of tearing up by the roots the most fundamental feature of our commercial and industrial life? Were all the scientists and engineers of the world brought together, it is doubtful whether they would make a city as large as Buffalo. Is it another case of infant industries, or, to vary the quotation used a short time ago, "Shall the mountain go to Mohammed at last?"

Physicians use the metric system, claiming simplicity, but they constantly study to mystify the people by calling common salt sodium chloride or natrium chloride, define water as aqua pura or

aqua distillata, etc., and should this system of weights and measures become general they would undoubtedly seek another, or their day of mystification would soon pass.

It is said that the naval architect desires the metric system because of the ease of transforming water displacement to kilograms, but unfortunately the naval architect deals principally with salt water. If the creator would kindly reconstruct the earth and fill the seas with distilled water, such argument might apply to his case.

The electrician desires it (and, by the way, the 21 letters from "large manufacturing firms, particularly manufacturers of machinery" that were sent to the House Committee were almost wholly from electrical concerns) that he may express 1 foot pound, that is, the energy required to raise 1 pound 1 foot high, by its much simpler metric equivalent of 13,562,600 ergs, a quantity in either limit beyond the comprehension of any created being, but they have shown such versatility and originality in their choice of units (and physicists, whose sole object appears to be mystification, might here be included), such as Radians, Dynes, Ergs, Ohms, Mhos, Volts, Farads, Joules, Watts, Henrys, Gilberts, Gausses, Maxwells, Oersteds, etc., such extreme readiness to assimilate the nature of a force to its descriptive name, that it is scarcely to be wondered at that they prefer, for a unit of measurement, something practically without a home and without a meaning. Electrical equivalents and formulæ are among the infant industries that desire protection at other people's expense. Is it advisable to go to the necessary expense for the benefit of the electrical engineers?

As to units of weight, which depend on the force of gravity, the result of the change will be (scientifically) to change from one interminable decimal to another. There is no unit of more universal application than that of gravity, and it is no easier for scientists to use 9.8026 meter than 32.161 feet, which, in our latitude, express that force to the same degree of accuracy. The accepted values of the dyne and erg are approximately correct at sea level in latitude 45 degrees, but nowhere else, and if the change is demanded in weights for scientific purposes—that is, for rigid accuracy—it is up to science to prove why one of the above values is simpler than the other. The force of gravity defies any system of division and laughs at legislation.

The indications are that the American Society of Mechanical Engineers will be overwhelmingly against the measure, and the statement made before the House Committee that the American Society of Civil Engineers favored it is untrue. Our retiring

President holds a letter from the Secretary of that Society, dated November 19, 1902, in which it is stated that the Society has never voted upon it.

What does the civil engineer gain by it?

True, he does some work where each piece is complete and finished in itself, and his unit of measurement is comparatively unimportant, therefore standing on a different basis from the mechanical engineer, a large majority of whose constructions are subject either to constant repair or interchange of parts, yet, so long as any existing structure remains, so long will the measures in which it was built remain. Measures are tied irrevocably to the past.

St. Louis measures its land to-day by the arpent used by the original French settlers. Philadelphia still has its chain of 100 feet 3 inches. Texas has its vara (and there are a great many varas in existence) and no amount of legislation can or will change the measure that is of the past.

The exemption of the United States public lands from the operation of this law recognizes this fact, but in order to testify in court, will not their $\frac{1}{4}$ sections of 160 acres each have to be referred to as measuring 0.804657 kilometer on a side, and having an area of 64.7474 hectares?

Take our drawings. We must choose some scale. Will it be more convenient to record 1 inch as 0.0254 meter, or to record 10 feet as 3047.945 milimeters? Where will be the room for the drawing when the dimensions are put on?

Take a homely little problem in city surveying. Suppose a lot 30 x 120 feet, on a street 66 feet wide, and suppose a sidewalk 4 feet wide, and a paved width of 32 feet. Now, shall the street be recorded as having a width (Kater's meter) of 20.1164 meters, or 201.164 decimeters, or 2011.64 centimeters, or 20116.4 millimeters? Not one of us could form a conception of the width from the latter figures. But it may be said that it will be very simple to alter that street width to 20 meters. Such alteration, however, would only involve the transference of a strip of land 5.82 centimeters wide by 9143.835 millimeters long to every owner of a 30-foot lot, and his 30 x 120-foot lot would become 36.6335 meters deep by 91.43835 decimeters wide, with a legal walk 1219.18 millimeters wide in front of it, and he would be assessed for paving not 30 x 16 feet, but 9.1438 x 4.8767 square meters. This may look absurd, but remember—linear measures are tied irrevocably to the past, and a hundred years from now the purchaser of such a lot can demand the amount of land represented by 30 x 120 English feet

of the year 1902—and obtain it, and posterity must know what that measure was.

The most difficult part of mathematics for students to grasp is decimals, and wherever possible they are avoided by business men; and, educated gentlemen though you are, it would be perfectly safe to assert that there is not one of you who could not easily be made to stumble over this mode of calculation.

Looking over the metric system you will perhaps be surprised to find that it is not so simply decimal after all.

The unit of length is a meter (39.37 inches by law).

The unit of solid measure is a stere and is 1 cubic meter (35.317 cubic feet).

The unit of square measure is the are, but it is not one, but 10 meters square (1076.4+ square feet).

The unit of weight is the gram (0.0022 pound avoirdupois), but it is not 1 cubic meter, but 1 cubic centimeter; and the dekagram, or ten grams, is not 1 cubic decimeter, although it is 10 cubic centimeters, the cubic decimeter being equal to 1000 grams, or 1 kilogram.

The unit of dry and fluid measure is the liter (0.0353 cubic foot), but it is neither 1 cubic meter, like the unit of solid measure, nor 10 cubic meters, like the unit of square measure, nor 1 cubic centimeter, like the unit of weight, but is one cubic decimeter.

In fact, the bases of the different weights and measures are as variable as our own, and the claimed facility for theoretical transformations will vanish like the dew of the morning when brought before the light of day.

The writer has transformed a great many formulæ from one system of measures to another and knows whereof he speaks.

The House Committee report also states that the Department of Education estimates two-thirds of a year saved in the life of every child by the use of the metric arithmetic. On the contrary, it would add that much more study, because measures are tied irrevocably to the past.

We may also ask, from this standpoint, How long will it take and what will be the expense incurred, to rewrite and reprint all of our existing text-books, histories, encyclopedias, records, etc., that we may save the two-thirds of a year in the life of every child as above stated, in order that they may *not* be able to read the history of their native country?

To what use are our public libraries doomed?

Finally, none of you are school children, but kindly listen to the following short table in the smallest French unit, in which the

decimals are not carried beyond the accuracy now obtainable in mechanical work.

¼ inch	= 6.3499 m. m.	1¼ inches	= 31.7497 m. m.
½ "	= 12.6999 "	1½ "	= 38.0996 "
¾ "	= 19.0498 "	1¾ "	= 44.4496 "
1 "	= 25.3998 "	2 "	= 50.7995 "

Now, linear measures being tied irrevocably to the past, who of you can tell me how many meters are represented by 1¼ inches?

You have just heard the answer.

DISCUSSION.

The President.—The newly elected Director, Mr. S. M. Kielland, will now make some remarks about the state of the metric system in Germany.

Mr. Kielland.—We know that Germany is a very disciplinary country; that is, they introduce a measure and carry it through by government order—soldiers. Still, within the last month, there has been introduced in the German Reichstag a motion to legalize the use of the ½ pound and ¼ pound as part of the national system of weights, it having been found impossible to familiarize the common people with the use of that kind of unit unless divided into halves and quarters.

As Mr. Tutton said, measures and weights are not especially for scientific people, they are not for that part of the world which may be possibly represented only by the people of Buffalo, but they are for the multitudes, for the common people; and it seems to me that these people should be considered when such a measure as this is taken up. It is not alone for us who have been trained, who are able to transfer from one thing to another, who can figure in the decimal or in the duodecimal system, but for the common men; and it seems to me it is a great triumph for those who oppose the metric system that this proposition is now before the German Reichstag.

I was born in a country where a binary system, similar to that of America to-day, pounds and feet, was changed to the metric system. It was a "craze," when, some years ago, old nations looked to France for pretty nearly everything in scientific lines. Educated people began to think that what came from France was the proper thing to follow; and, without taking time to look into or study the matter, the metric system was adopted by pretty nearly all of the leading nations of Europe, with exception of the Anglo-Saxon nations and Russia.

When I went over to Norway, Sweden and Denmark, a few years ago, after having been away about twenty-five years, I found the common or old measures, as well as the metric measures, in use by the common people, especially among the traders and peasantry. The most of their trade and dealing is done by the old system, the same as they used to do before the metric system was adopted. Of course, if we want these difficulties and complications by the use of two or more systems, which Mr. Tutton has so well pointed out, we can have them by making the use of the metric system compulsory in the United States.

America is to-day a mighty nation. We are taking our share (pretty near the governing share, you might say, from one-half to one-third) of the business of the world, and why should we change our system now? Let them change theirs to ours.

Col. Francis G. Ward.—I was brought up under the metric system and so might differ somewhat from the gentlemen as to the application of it. I resided for eight years in a country where the people were familiar with its use. I doubt whether it is advisable to adopt it in the United States.

The standard, as made and elaborated in France, is certainly figured out as finely and as carefully as any system can be. Naturally, when you begin to compare it and translate from one system into another, you meet the same difficulties as translating from one language into another. You lose the value of any work when you translate it. You should be able to read the work in its original. If there is to be a universal system of measures in the world, and if there were a movement in all countries which would bring all measures to a uniform standard scale, meters or any other system, I believe that such universal measure should be adopted. To the people that have been accustomed to use the metric system it would sound like heresy to say what you have said to-night about the metric system, and I want to qualify my remarks and say that I realize the difficulties of translating one system into another. The system that we have in this country is the old English system. *Good enough for us.*

I do not believe there is any necessity for any change in the system of measures of the world until we have a universal measure, the same as the Postal Union, the same as we have arbitration, then the best scientists of every country should be brought together and formulate a universal system. I would not say a metric system, but I would say a universal system which could be used by the commerce of the world. A short time ago Mr. Tutton spoke of the commerce of the world. One of the criticisms upon our manu-

facturers is that they will not comply with local ideas and local institutions in the packing up of their wares. That they insist upon using measures, forms, weights and everything that we use in this country. This criticism is from the *other side.* It is the criticism of the people that we sell to in South America. I have had some conversation on that point. They do not not like it. They do not want our weights or packages. The French and Germans are superior to the Americans in their foreign export trade. I speak of those things as I find them, without any very great knowledge on the subject.

Mr. Geo. B. Bassett.—I know very little about the metric system. I think its adoption as an official standard in this country would burden the country with two systems; instead of leading to simplification of matters of weights, measures, etc., it would really complicate them. As it is now, our system of weights and measures is quite simple and readily learned, and it would be difficult to do away with it.

Personally I am not in favor of the change.

Mr. Geo. F. Morse.—Everyone knows that the metric system is the only lawful system in Latin countries, yet a commission merchant in New York city exported to Porto Rico, and I believe to Honduras, a great many scales which were marked with the metric system on one side and pounds on the other, because people in those countries knew of the English pound, but there was this peculiarity about those scales, the Government inspectors only inspected the metric system, while the pounds were equivalent to about twelve ounces of American pounds.

Col. Ward.—A man in France, selling by kilos, gets the advantage in weight over an American who buys by pounds, and it is to their advantage to keep up a difference in the measurements and weights. It is a commercial proposition and I believe it will be difficult to get over it.

Mr. Tutton.—I am fairly familiar with foreign sciences, and it is science that particularly demands this change. Now, anyone reading foreign scientific books will find that they practically reduce all units to three divisions, the unit and the thousand. The kilogram, gram and milligram, the kiloliter or cubic meter, liter and milliliter, etc. They recognize nothing between these to speak of, and while it is easy for a scientist to say 1/100 and 1/1000, when you come to the people, they are not in it. They are not educated to this point and you never will be able to educate them to it.

Fancy a woman asking for a thousandth part of a kilogram of something, or even a hundredth. She might be educated to know

what a dekagram or hektogram is, but she could never be educated to know what the 1/1000 of a kilogram is. There is no objection to scientists using this system, if they find it convenient, but because scientists want it, don't saddle it on the common people. Scientists are too few in number.

Vice-President Norton then spoke about the uncommon units of English measure, like the measurement of "finger lengths" in knitting, and of knots and skeins, as well as many other measurements in common use throughout the country.

Mr. Norton then continued as follows: Any change which we might adopt officially would, with the common people, have no effect for a long time, but that is not a question which should be brought into this argument. The fact is that these systems are slow of change and are changed only through the lapse of generations. It is a question whether or not to-day the metric system is more convenient and better for use and can be adopted with less inconvenience to the people than some other whereby we may arrive at a universal system. It is a question of the merits of the system. I do not doubt that we are coming in the course of time to some universal system of measurement. Whether it is going to be the metric system or some other, I think it is too early in the discussion of the subject for anyone to say, and it would seem to me that the time has not arrived yet for the United States to change, but it may be desirable. The question has not been sufficiently considered as to whether that is the easiest and best, and in the end most satisfactory method of arriving at a universal system of measurement.

The President.—Mr. Herbert Spencer wrote a letter (which is printed in his miscellaneous writings) to a member of the House of Commons of the English Parliament, who was chairman of the committee who had in charge a bill similar to our present H. R. Bill 123. In this letter Mr. Spencer stated that although the metric system was used by the Latin nations of Europe and America, yet that in all of North America with the exception of Mexico, in all of the British Empire and in all of Russia, the countries comprising one-third of the land area of the globe, they did not use the metric system, and he also stated that Anglo-Saxons and Russians manufactured more than two-thirds of all the manufactures of the world, or of the civilized nations.

In bringing this matter before the Society at the present time I did not have in mind the discussion of the metric system itself, but I desired to get an expression of the views of the members as to the necessity of passing the bill now before Congress, without

any discussion thereon by the people at large, or without any demand for it coming from any State or municipality.

In order to find out the present status of the bill, I addressed a letter to Hon. D. S. Alexander, one of our members of Congress, who in turn wrote to the Hon. J. H. Southard, Chairman of the Committee on Coinage, Weights and Measures. I will read you his reply:

TOLEDO, OHIO, October 29, 1902.

HON. D. S. ALEXANDER, Buffalo, N. Y.

My Dear Alexander:—I have yours of October 27th, and will say that at the last session of Congress a bill providing for the adoption of the metric system by the departments of the Government was reported favorably to the House and is now on the calendar. It does not affect the general public otherwise than indirectly through the departments of the Government. If the bill becomes a law the different departments will be required to establish the weights and measures of the metric system in all Government transactions after the first of January, 1904. Very truly yours,

J. H. SOUTHARD.

During the discussion of this bill last summer by the Western Society of Engineers it was stated that members of Congress wished to have the opinions of "civil engineers and other practical men" on the subject.

It will be noted that Mr. Southard says that this bill does not affect the general public otherwise than indirectly, etc., a statement which seems to be contradicted by the wording of the bill itself. If members of Congress would like to have the opinion of "engineers and other practical men," they should invite discussion on the subject by the common people, but no such discussion was had, to my knowledge, in any congressional district during the recent political canvass.

MR. BASSETT.—I think before such a radical change is made, it should be submitted to popular vote, like a change in the Constitution of the United States.

MR. KIELLAND.—It seems to me that the utterances we have heard to-night are a pretty fair indication of the general opinion which would prevail in the United States if this matter was brought, as it should be, to the full hearing of the American people. This is not a matter which should be passed on by a few scientific bodies. The American people should have more to say, should have more chance and time to decide a matter of such vast importance as changing the weights and measures. Therefore, I advocate a motion that our members of Congress have from this Society an opinion that we think that the matter is untimely; that it has not been sufficiently discussed throughout the country, and that its passage, without such discussion, would be premature.

OBITUARY.

Moses W. Oliver.

Member of the Boston Society of Civil Engineers.

[Read before the Society, February 18, 1903.]

Moses W. Oliver was born in Athol, Mass., in June, 1823. He was the son of George and Deborah White Oliver. His mother was born in Warwick, Mass., but no further details about his parents are known. He received a common school education, and went away from home at a very early age to work in a cotton factory at Peterborough, N. H. He had a half brother, Samuel C. Oliver, who was superintendent of the mill where he worked. While working at the mill he displayed a marked natural ability in drawing, and, being encouraged by his friends, he decided to obtain suitable books and pursue a course in civil engineering without a teacher, working in the mill all day (and the days were long at that time) and pursuing his studies by night, using every opportunity and securing the best books to be had to help him in his chosen profession. After several years of hard study he was employed in the civil engineering department of the Boston and Lowell Railroad, and in 1848 he was assistant engineer on the Nashua and Lowell Railroad, which was then constructing the Stony Brook Railroad, a branch road in Massachusetts, and the Wilton Railroad, a branch road in New Hampshire. After completing his work on these roads, he took a position in the engineering department of the Amoskeag Manufacturing Company, of Manchester, under the late Hon. E. A. Straw, where he remained employed in the general engineering work of that water power company.

While in the employ of the Amoskeag Company a great freshet occurred in the river, and, the weather suddenly becoming cold, froze the surface of the enlarged river above the Amoskeag Company's dam. On the subsidence of the water he went over the flooded region, and by the remains of the ice was enabled to drive nails into some of the prominent trees, thus recording the height attained by the water. Many years afterward a question of damage from flowage came up and he was able, from these nails, some of which he found, to establish some very desirable facts bearing on the case.

In the summer of 1853 he accepted a situation on the Marietta and Cincinnati Railroad, in Ohio, in which position he remained two years, returning in 1855 to Manchester and opening an office

for general engineering work, particularly relating to the construction of cotton mills. Among his works of this description was the construction of the new mills at Indian Orchard, Mass., in 1859, finishing in the spring of 1860; also a new mill for the Hamilton Woolen Company, at Globe Village, Southbridge, Mass., finishing in the spring of 1861. He then had charge of rebuilding No. 1 Mill of the Manchester Mills, being completed in January, 1862. It was in connection with a small annex of the Manchester Mills that the first solid plank and timber roof was built, from which it appears that Mr. Oliver is entitled to the credit of having originated and designed this form. The earliest mills at Lawrence, Manchester and Lowell were built with steep pitched roofs. A little later some roofs were built flat and covered with tin, and still later, with the invention of coal-tar roofing and other plastic coverings, the flat roof found many advocates, but was commonly built of inch boards laid on roof joists of plank on edge, ranging from 2 to 3 inches in thickness and from 8 to 12 inches in depth, spaced 16 to 24 inches apart; in fact, almost precisely the same type of construction as is to-day followed by the average architect when he has a flat roof to build. Mr. Oliver conceived the idea of massing these roof joist into solid timbers 10 x 12 inches or 12 x 16 inches, according to span, spaced 8 to 10 feet apart, and then covering the whole with plank from 2 inches to 3 inches in thickness. The substitution of 3-inch plank for 1-inch boards gave a thickness of lumber which afforded an excellent non-conductor against the cold of winter or the heat of summer, without the necessity for an air space, but at the same time it gave a rigid platform, which afforded much more substantial support for the plastic roof, and, therefore, added greatly to its durability and freedom from leaks caused by warping or by the springing in of the boards when workmen or others had occasion to walk over it. The substitution of the single solid timber for the half dozen or more thin joist gave a ceiling of much better appearance and avoided the necessity for covering it with sheathing. The doing away with the air space added greatly to the ease with which a fire could be extinguished in its incipiency, and whereas a fire that continued long enough to burn half an inch off each exposed side of a 2 x 12-inch joist would so weaken the joist that the roof must fall, more than double this amount could be burned off each exposed surface of a 10 x 14-inch timber having an ordinary factor of safety and leave abundance of strength to support the roof until repaired. The merits of this form of roof had only to be seen to be appreciated, and it has now for forty years been

the standard form of roof construction in the great majority of the New England factories.

On January 1, 1868, he was appointed engineer in charge of repairs and renewals of bridge building and permanent way of the Boston and Lowell and Nashua and Lowell Railroads, then being operated jointly under the management of Gen. George Stark. He retained this position for six or seven years. During this time he had charge of constructing the new terminal for the Boston and Lowell Railroad in Boston, involving a passenger station costing $1,200,000, reconstructing passenger and freight bridges and keeping all the daily traffic moving on time. In building the terminal station at Boston there was found in one of the towers, when partially completed, a serious defect, but, through the engineering skill of Mr. Oliver, it was so strengthened as to make it advisable to continue building. He built the connection between the Boston and Lowell and the old Lexington and Arlington Railroads, and built the Mystic River Railroad, connecting the Mystic Wharf property, at Chelsea Bridge, with the Lowell Road, extended the Lexington Railroad to old Concord, relocated and built the branch from Wilmington to Wilmington Junction, made surveys for a terminal in Lawrence, surveys and plans for the remodeling of yards and tracks at Lowell, new iron bridge across Pawtucket Canal, reconstruction of terminal facilities for Stony Brook Railroad at Ayer Junction, surveys, plans and construction of the Wilton Railroad, in New Hampshire, to Greenfield, N. H., a new roundhouse at East Cambridge, a freight house at Lowell and one at Ayer Junction, together with many other minor improvements which were successfully completed. He surveyed the neighborhood at Lawrence to determine the feasibility of the Boston and Lowell Railroad entering the city some years before they decided to do this. At this time he recommended very strongly that the city should be entered by building a bridge across the river above the dam, thus enabling the Boston and Lowell Road to extend their tracks beyond the city in any direction and giving them many advantages over the Boston and Maine.

He was employed by the Merrimack Company of Lowell as their engineer at various periods. He came to Lawrence in 1882 to reside, and was employed by the Pacific Mills from November 20, 1882, until November 1, 1884. In August, 1885, he was again employed, and worked more or less until March, 1886. During these years he made plans for the reorganization of their card room, built their No. 5 storehouse, put new foundations under the columns of their main mill, 806 feet long and seven stories high,

and replaced all wooden columns in the two lower stories with iron ones. He took great care in this work to have accurate bearing surfaces for the columns, and also calipered the thickness of each column on four sides for every foot in length to insure uniform castings. It was a pet theory of his that some time columns for a factory would be bolted together to make them continuous.

He also designed the branch railroad track running to No. 6 storehouse and superintended the erection of the abutments and bridge across the canal. During the fall of 1885 he put in four steel penstocks 7 feet in diameter and each 140 feet long, with the necessary head gates, etc. He also made various plans for rearranging the water and steam plants at the mills, although the plans have not yet been carried out. During these years he did considerable work for the Atlantic Mills in building their tower and widening one of their buildings. Here, for the first time, he adopted the plan of battering the walls from the outside instead of offsetting on the inside; his claim was that in case of fire it was much better that the walls should fall in rather than fall out. It has been stated that he originated the pilaster and broadened walls used in modern mill construction, thus allowing larger windows and increased lighting.

At the Everett Mills, in 1886, he built an extension to the picker room, extending it up two stories; the same year he designed and built a coal pocket of 5500 tons capacity, and in 1892 designed and built a new mill, No. 4, for spinning and weaving. All the tracks, switches and frogs about the yard were laid under his supervision, and fulfilled their purpose in a perfect manner.

He also designed and put in penstocks for the Munroe Felt and Paper Company and the J. P. Battles Company at about this date. His health gradually failing, he relinquished much of his active work and amused himself in designing new forms of rails and other details of engineering work. He also had some scheme for developing power in an entirely new and, as he claimed, a very efficient manner. This was never put into practical shape, although he had certain portions of the machinery built about a year before his death.

Mr. Oliver was a self-made man in every sense of the word, a close student, an untiring worker, a genial character to meet, and eminently just and strictly honorable in all his dealings with everyone. With determination to excel, he worked himself to the front of his profession, and often had original and effective methods of solving engineering problems. His assistants have stated that

in general he would not trust his subordinates to work out all the details of various problems, but insisted on going over all the points with great fidelity, oftentimes at the expense of overworking himself and causing delay.

He married Esther L. McAllery, of Merrimack, N. H., and they lived happily together until March 15, 1897, when she was removed to the other world, and he followed about three years later. They had no children, and the only known relatives were a half brother, Samuel Caleb Oliver, and a sister, Miss Cynthia Oliver, living in Nashua.

Mr. Oliver was interested in educational matters, and showed his good will in a practical manner by leaving a small legacy to the Massachusetts Institute of Technology for general uses in connection with the school. He attended the Unitarian church, and was very conscientious in all matters relating to a religious life.

Mr. Oliver died September 8, 1900, after a short illness, of pneumonia, aged seventy-seven years and three months, and was buried in Manchester, N. H.

RICHARD A. HALE,
ARTHUR D. MARBLE,
Committee.

OBITUARY.

Frank E. Fuller.

Member of the Boston Society of Civil Engineers.

[Read before the Society, January 28, 1903.]

Frank E. Fuller was born in West Newton, Mass., April 28, 1871, the son of J. Cheever and Laura Eaves Fuller, and a descendant of the ninth generation from John Fuller, one of the first settlers of Newton in 1644 (born 1611 and died 1699).

He received his education in the public schools of Newton, graduating from the high school in 1890, and entered the Chandler Scientific Department of Dartmouth College. Owing to serious illness he was obliged to give up his studies, much to his regret, and traveled to Jamaica and Europe to regain his health.

During his summer vacations of 1886 to 1889 he worked in the city engineer's office in Newton, and on his return from Europe he re-entered that office, where he remained till 1895. During the work of depressing the railroad through the Newtons he was connected with the engineering department of the Boston and Albany Railroad, looking after the masonry work.

In 1898 he entered the engineer's office of the Metropolitan Water Works, where he remained to the time of his death.

From a youth he was much interested in microscopic study and research, and in 1900 was appointed bacteriologist on the staff of the Newton hospital, which position he also retained until his death.

From close application to work and study his health failed again, and in December, 1901, he went first to Buenos Ayres, Argentine Republic, and thence to Teneriffe, Canary Islands, to recuperate, but grew worse and died at Teneriffe on August 1, 1902. He leaves a widow, Mary E., daughter of the late Benjamin F. Houghton. She was with him at the time of his death.

Mr. Fuller was elected a member of the Boston Society of Civil Engineers on December 16, 1896. He was also a member of the New England Water Works Association and of the Beta Theta Pi Fraternity.

Charles W. Sherman,
Henry D. Woods,
Committee.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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ON THE USE OF BEAUMONT OIL AS FUEL.

BY HENRY H. HUMPHREY, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, April 2, 1902.*]

A LITTLE more than a year ago the first discovery of oil was made at Spindle Top, near Beaumont, Tex. It was the writer's privilege, in the interest of a client, to visit these oil fields in January, one year after the first discovery of oil. Riding out from Beaumont through the flat rice lands of Southeastern Texas, one pictures a beautiful mound rising above the plain and surmounted by derricks, but this picture of the imagination is doomed to disappointment. Spindle Top is, perhaps, 10 or 12 feet high, as the surveys show it, but the rise is so gradual that the ground appears level. The derricks are there, standing as thick as they can be crowded and looking like a forest of pines in the distance.

At that time there were about 150 wells, all grouped within a space not exceeding 235 acres in extent. These wells vary in output from 10,000 barrels to the largest, which flows approximately 80,000 barrels per day of 24 hours. The only limit to the flow of oil appears to be the size of pipes, as the largest wells flow with the same pressure as the smaller ones. The total output of these wells would reach the enormous quantity of over 7,000,000 barrels per day should they all be allowed to gush at the same time and should the pressure remain undiminished for 24 hours. This output of oil almost exceeds the limits of the imagination, and is more than a year's output of such well-known older districts as the Indiana oil fields.

Even with this immense output available the consumption of Beaumont oil has hardly begun. A well-known shipper in Hous-

*Manuscript received April 2, 1903.—Secretary, Ass'n of Eng. Socs.

ton, having very complete data regarding the shipment and use of oil, stated that but 3 per cent. of the steam boilers of Texas has been equipped with fuel oil burning apparatus during the first year. The average daily shipments are estimated at 16,000 barrels. I believe that this exceeds, rather than falls short, of the actual shipment.

The price at the wells has dropped until, at the present time, it is from 9 to 10 cents per barrel f. o. b. cars. The price at other points depends entirely upon the freight rate and the expense of delivery from the railroad to the user's plant. The price quoted me in St. Louis last week by one large shipper of oil is $1.14 per barrel f. o. b. St. Louis, of which price $1.05 is paid for freight. It is found that, at the present prices for oil, few of the oil companies desire to make long-time contracts, and the prospect is that prices will go higher rather than lower in the future, notwithstanding the inexhaustible supply.

The importance of this oil discovery can be appreciated when it is recalled that the Texas coal fields are limited in extent and the quality is poor. Fort Worth coal varies in quality from that having 9500 heat units per pound to the best, having 11,800 units per pound, and the lignite from the mines in the eastern part of the State are of much poorer quality. The next best source of supply is from the Arkansas fields. This coal contains about 11,400 B. T. U., and costs in the neighborhood of $2.30 per ton delivered at consumer's plant at Northern Texas points. The best steam users' coal reaching Northern Texas markets is the McAllister coal from Indian Territory. It contains about 13,500 B. T. U. per pound. Its cost, delivered, varies from $2.50 per ton for pea and slack mixed to $3.40 per ton for run-of-mine coal.

The use of crude petroleum as a fuel is in many respects ideal. It does away with all dust and dirt about the building from the handling of coal and ashes. In the case of a first-class office building in the heart of a city this is an important consideration. When properly burned it is a smokeless fuel, thus complying with the requirements of large modern cities and possessing a desirable feature to all users of steam who take a pride in the cleanliness of their city. I say that when properly burned it is smokeless, as it is possible to make an oil-burning plant as smoky as when using the poorest of soft coal. It is by the proper regulation of the atomizer producing a complete atomizing of the oil, and also by the proper supply of air producing complete combustion, that the burning of oil is found to be absolutely smokeless. A further advantage in the use of this fuel is its accurate regulation to the requirements

for steam, thus insuring a uniform steam pressure. There is also a great saving in large plants in the item of labor, although in smaller plants this saving is not effective, as it is not practicable to operate boilers without someone in attendance. It is a clean fuel, making it possible for the boiler room to be kept as clean as any well-cared-for engine room. Where oil is used, it is quite common to see the boiler fronts, walls, etc., neatly whitewashed, presenting a very attractive appearance. It is also much easier to keep boilers clean where the oil is used as fuel, as the practically complete combustion of the fuel leaves little soot to be deposited upon the boiler tubes. It is my belief, also, that by the use of oil the fire risk is lessened, although insurance companies have not yet arrived at the point where they look at the use of oil in this light. Oil spilled upon the boiler room floor by accident will not burn when a lighted match or burning coal is thrown upon its surface. There is no odor in the boiler room from the burning of fuel oil, although it is a common impression that such is the case. With the use of oil there is no necessity for opening and closing the fire doors of the boiler, and the boiler is not thus subjected to the strains of receiving cold air on highly heated surfaces. The accurate regulation of air to the requirements of the burner, as well as the accurate regulation of oil to the requirements for steam, make it possible to secure better economy in the use of fuel than is possible by any method of firing coal except the most expensive of automatic stokers. It is also possible to get up steam quicker when using oil than when using coal, and the boiler also responds quicker to changes in load.

The disadvantages in the use of fuel oil are few. Some types of burners make considerable noise, which would be objectionable in some locations. The space required for storage tank is a serious objection to the use of oil in many places, as it will be found impossible to find room for the tank without having it occupy a valuable space. There is also an odor from the storage tank when filling from the car or other source of supply. There is also considerable uncertainty regarding the delivery of oil at present, as shipping arrangements are not as well systematized as in the case of the supply of coal. There is also the disadvantage that the atomizers use some steam, the amount varying from 3 to as high as 13 per cent. in some cases. The use of compressed air instead of steam for the operation of the atomizers is to be recommended in all cases where a source of compressed air is available.

With all of these advantages in the use of oil, and with so few disadvantages, and added to this, with the price of oil as low

as 9 to 10 cents per barrel of 42 gallons at the wells, and with coal at the high prices mentioned above, it is not surprising that steam users throughout the State of Texas are at present investigating the merits of this new fuel or are equipping their plants for its use.

The first question presented to the prospective user of oil is, How will it affect the insurance? The underwriters have made a study of the use of oil as fuel, and have hedged its use about with certain essential restrictions. They require that the tank for storage of oil supply shall be of boiler iron, of No. 18 galvanized iron or steel; shall have ventilation at top and shall be located not less than 50 feet from the building if wholly underground or 100 feet if wholly or in part above ground. In the latter case the tank should be inclosed in a substantial brick or stone wall or earth embankment of sufficient capacity to hold contents of tank in the event the oil is released from any cause, and in every case the tank shall be so placed that the highest point in said oil supply shall be lower than the furnace where such oil is to be burned or converted for burning.

"The conveying of oil to furnace shall be by artificial pressure or suction either by pump, vacuum or other means that will accomplish the purpose. This expressly prohibits the feeding of oil by gravity and pressure or by other means from the storage supply higher than the furnace; provided, however, that oil may be fed to burners under a maximum pressure of 8 pounds to the square inch from an iron standpipe having a maximum capacity of 5 gallons, located at storage tank and supplied from storage tank by pump while the oil is being conveyed to furnace. Standpipe shall have an overflow pipe (with capacity equal to discharge pump) leading back to storage tank and shut-off cock where supply pipe leaves standpipe for furnace."

Many different types of apparatus for the burning of crude petroleum are on the market, all complying with the underwriters' requirements as above outlined. These equipments vary from the simplest, consisting of a No. 18 galvanized iron oil-storage tank, with ventilators, standpipe, pump and burner. The latter is sometimes home-made, although generally one of the well-established types of burners on the market is used. These burners are introduced into the furnace doors generally interfering as little as possible with the boiler front. The grate bars of a common furnace are covered with fire brick and a broken network of fire brick laid up, or sometimes only a rough pile of fire brick, upon which the flame of the oil is allowed to impinge.

From this cheapest possible outfit to the best is a long step. The best equipment consists of a steel oil-storage tank, with flanged outlets and ventilating pipe at the top, equipped with an indicator showing the amount of oil in the tank. This tank is also furnished with a pipe for heating the oil with steam to keep it in a liquid condition in cold weather. The pumping outfit consists of a duplicate set of duplex pumps, mounted upon a table and surmounted by a small filtering tank, which also contains a coil of pipe for heating the oil. This pumping equipment is properly valved and dripped, provided with thermometer, gauge glass and pump governor.

The burner is of special design, receiving the oil through a central tube through which steam at 50 pounds pressure is taken, atomizing the oil. This burner is set in a special tuyere block for the admission and regulation of the free air necessary for complete combustion.

The changes in the boiler setting comprise a special study in each particular case. These changes generally consist of the installation of a fire-brick lining over the grate bars and a special checkered baffle wall of fire brick, and behind this, near the rear of the boiler, another wall intended to retard the velocity of the heated gases, and the whole designed with the idea of diffusing the heat of the flames and preventing its localization to the injury of any part.

It is interesting to observe, in this connection, that the plant of the World's Columbian Exposition was equipped with the highest class of fuel oil burners, this being one of the largest plants that have used fuel oil in this country. That plant contained approximately 25,000 horse power of boilers. The engineers in charge of that plant found that the best results were obtained when the oil was heated to a temperature just below its distilling point before being delivered to the oil atomizer. They found this preliminary heating of the oil insured a speedy vaporization at the burner, with a resultant flame soft and diffusing, and not sharply impinging upon boiler surfaces. They also discovered the advantages of using low-pressure steam to vaporize the oil in the burner.

The plant under consideration in Dallas, Tex., consists of two 100-horse-power standard water tube boilers, operating at 100 pounds gauge pressure. The draft is good, and feed water enters the boiler at from 208 to 210°. The cost of coal delivered in the building is $2.50 per ton for a mixed pea and slack McAllister coal. The use of coal is about 4½ tons per day, and the plant operates 17 hours per day. The coal bills average about $375 per month

during the fall, winter and spring months, when considerable lighting is being done.

The writer's attention was first directed to the use of oil in this plant during the month of February, 1901. At the request of his client, he visited the electric-light plant in a nearby village, which had in previous years operated with crude petroleum, the refuse of the Corsicana Refinery. During last year, however, as the price of oil had risen, this plant had returned to the use of coal. The recent discovery of oil at Beaumont the month previous had so reduced the price of the refuse from the Corsicana mills that the use of this fuel had again been taken up. The following data were obtained from this place:

During the months of September, October, November and December, 1899, this plant had used oil costing 88 cents per barrel of 42 gallons, delivered in storage tank at the plant. The total cost of oil burned during these months was $1072.00. The total output in K. W. hours, taken from the switchboard records, was 122,045 K. W. hours. During the corresponding months of 1900 Arkansas coal had been burned, at a cost of $2.35 per ton delivered, the coal bill amounting to $1350.38. The output of the plant during this period was 140,085 K. W. hours. The cost of oil per K. W. hour was $0.00878; the cost of coal per K. W. hour was $0.00964, a saving in favor of oil under these conditions of 10 per cent.

This figure refers to fuel alone, and does not take into consideration any saving in labor, although one man operated the entire plant when using oil, while, when using coal, a fireman was employed in addition to the chief engineer or man in charge of the station. The oil-burning equipment was of the simplest kind, consisting of large storage tanks about 100 feet from the plant, a small tank on the roof of the plant, and pump for filling the small tank while the plant was in operation. Steam for the operation of the oil atomizer was taken direct from the steam main and reduced by throttling by means of a valve near the burner.

Recent inquiries made among the users of Beaumont oil in the State of Texas have brought uniformly favorable reports.

A city in Northern Texas operates for its water and light department two 150-horse-power boilers. Beaumont oil costs it 47 cents per barrel delivered in its tanks. It had formerly used McAllister mine-run coal, at a cost of $3.45 per ton delivered. The actual results claimed by it in the use of oil is a saving of 36 per cent. over coal at above prices.

A mill and elevator company in the same vicinity report having used lignite for fuel, at a cost of $1.35 per ton; Beaumont oil

costs them, delivered, $47\frac{1}{2}$ cents per barrel. They claim a saving of 40 per cent. by the use of oil compared with the use of lignite at above prices.

The comparative value of coal and oil is stated roughly to be from $3\frac{1}{2}$ to 4 barrels of oil, of 42 gallons each, as equal to a ton of coal. There is nothing definite in such a statement. The value of a ton of coal in the production of steam depends upon many other factors than that of price alone. The quality of the coal, the type of the boiler used, the design of furnace, the draft obtainable, the temperature of the feed water, the condition of the boilers as regards the amount of soot on the tubes, and, lastly, the method and care with which firing is done, all affect the pounds of water evaporated per ton of coal. It is also true that, in the use of oil, as much depends upon these same conditions. The amount of steam used by the atomizer itself varies in different equipments from 2 to 13 per cent. of the total steam generated when the boiler is operated at rating. A great deal depends also upon the proper adaptation of the furnace for the use of this fuel and upon the care with which the atomizer is installed and operated. We can only estimate, therefore, in a general way, what possible saving may be expected in the substitution of oil for coal in any particular plant.

In this plant I have estimated the coal to have a heating value of 13,000 B. T. U. per pound. I have estimated the boiler efficiency at 60 per cent. under average working conditions, where one boiler is operated close to three-fourths its rating for a large part of the day and at full rating or above for a few hours in the evening. The best data that I have been able to obtain give the heat units of Beaumont oil as approximately 19,000 B. T. U. per pound. The boiler efficiency guaranteed by the best class of oil-burning apparatus is 75 per cent.

These assumptions show that 1094 pounds of this oil are equal to one ton of this coal, or 3.1 barrels of oil are equal to one ton of coal. On this basis the cost of oil will be \$1.39$\frac{1}{2}$ for a steam-generating capacity equal to one ton of McAllister coal at \$2.50 per ton. Based upon a coal bill of \$375 per month, the figures show that this same plant can be operated by oil for \$209.25 per month, or a saving of 47 per cent. over the present cost.

Bids were received on oil-burning equipment for these two boilers as follows:

The storage tank to have a capacity of 11,000 gallons and to be located within 60 feet of the boilers, the tank to be made of 3-16-inch sheet steel with $\frac{1}{4}$-inch heads. The tank to have vent

pipe carried above roof of building, fitted with indicator showing height of oil and equipped with heating coil for the circulation of exhaust steam through the tank. The pumping outfit to consist of duplicate pumps, working on direct-pressure system, with regulator and small filter tank. The burners to be two in number for each boiler, all piped up complete, with steam connection to boilers and the necessary changes in the furnaces. All of this equipment to be erected complete in purchaser's plant and the efficiency of the apparatus in the use of oil fuel guaranteed. The following prices were obtained:

Bidders.	Price.
A	$704.00
B	936.00
C	1,209.50
D	1,389.22
E	1,500.00
F	1,525.00

Bids were also received upon oil delivered f. o. b. cars Dallas, Tex., for different lenghts of contract, as follows:

Bidders.	1 Year.	2 Years.	3 Years.
A	44¾ cents per bbl.	46¾ cents per bbl.	48¾ cents.
B			44¼ cents.
C	50 cents per bbl.		

One bidder only agreed to deliver oil in storage tank, and made a price of 60 cents per barrel delivered for one year's contract.

So much for the conditions existing in this particular plant at Dallas. But the question of more vital interest to us in St. Louis is, At what price must Beaumont oil be delivered in St. Louis to compete with Illinois coal? Let us assume, for the sake of convenience, a plant of the same size as the Dallas plant, and using the same amount of steam, but erected in St. Louis. The heat units of Mt. Olive coal are taken at 10,600 per pound, the efficiency of the boilers is taken at 60 per cent., the same as above. The heat units of Beaumont oil are taken at 19,000 per pound, the same as above. On this basis we find that 892 pounds, or 2.8 barrels, of this oil are equal in steam-producing value to one ton of Mt. Olive coal. Taking the cost of Mt. Olive coal supplied in power plants in this city at $1.70 per ton, the cost of Beaumont oil delivered in St. Louis must be as low as 60 cents per barrel to equal our coal in price, considered solely on steam-producing qualities. As stated above, the price of Beaumont oil quoted me last week, delivered f. o. b. St. Louis, was $1.14 per barrel. The freight consumes $1.05 of this amount, leaving but 9 cents per barrel for the cost of the oil at the wells. The use of Beaumont oil in our city,

whether by the World's Fair power plant or by smaller consumers, when considered on an economic basis solely, is entirely a question of transportation rates.

The contractors for the equipment of the Dallas plant guaranteed to evaporate 15 pounds of water "from and at" per pound of oil, the boilers to operate within 25 per cent, of their rating. Let us see whether such guarantees have been met by actual tests. In a test at the plant of the Dallas Electric Company, A. K. Bonta, engineer, an evaporation of 13.77 pounds of water "from and at" were obtained per pound of oil. Prof. J. E. Denton, in tests made at the West Side Hygeia Ice Company, New York City, obtained an evaporation of 14.80. R. W. Hunt & Co., in tests made at Washington Avenue Power House, West Chicago Street Railway Company, obtained an evaporation of 14.89. The engineer in charge of the Houston Street Railway Company, in tests made on his plant, obtained an evaporation of 13.58. An average of the above figures is 14.26, which approximates the guaranteed results.

An analysis of this oil will doubtless prove of interest, and I give below that made by Prof. J. E. Denton, the best authority that I have been able to find:

Specific gravity	0.92
Flash point (degrees Fahr.)	142
Burning point (degrees Fahr.)	181
Cold test (degrees Fahr.)	6
Calorific value per pound by oxygen calorimeter (B. T. U.)	19,060
Chemical composition, carbon (per cent.)	84.60
Chemical composition, hydrogen (per cent.)	10.90
Chemical composition, sulphur (per cent.)	1.63
Nitrogen (per cent.)	0.00
Oxygen (per cent.)	2.87

A competent authority reporting to the Bureau of Statistics at Washington gives the following as the cost for an average well on Spindle Top:

950′ of 4″ line pipe at 42 cents per foot	$399
950′ of 6″ line pipe at 72 cents per foot	684
800′ of 8″ line pipe at $1.10 per foot	880
400′ of 12″ line pipe at $2.04 per foot	816
Cost of drilling $4.50 per foot, average depths of 950′	4,275
Teaming, fitting and covering well	250
Derrick	135
Total	$7,429

To this should be added the cost of real estate, and one-thirty-second of an acre, giving sufficient room for the erection of a derrick, can be purchased on proven territory with the oil beneath it guaranteed, at not to exceed $5000, a total cost of well of $12,429.

RAINFALL ON THE PACIFIC COAST OF NORTH AND SOUTH AMERICA AND THE FACTORS OF WATER SUPPLY IN CALIFORNIA.

By Marsden Manson, Member Technical Society of the Pacific Coast.

[Read before the Society, December 6, 1901.*]

Two of our greatest industries, agriculture and mining, are entirely dependent upon rainfall. Water power, developed into and transmitted as electricity, is becoming of such great importance that even the lighting and car service of our cities are dependent upon a reliable water supply in some far-off mountain stream. Of still greater importance than these is the water supply of our cities, which, during the past years of deficient rainfall and of greater growth and demand, is assuming a phase which necessitates the projection and execution of works which are to last for many centuries to come. To insure the adequacy of these works, as to purity and abundance, is taxing the abilities of our profession throughout the State. This study of water supply is of vital importance not only to the engineer, but also to the farmer, because it affects his crops; to the capitalist, because it affects his profits and losses; to the miner, because it affects his returns; to the merchant, because it affects the stability of his credits and advances; to the owner of every home, because pure and abundant water is one of the elements of the health and well-being of its inmates.

The irregular distribution of rainfall in California from year to year, and the occurrence of wet and dry seasons, have imposed peculiar importance upon our modes of utilizing and conserving our water supplies. This irregular distribution cannot be fully understood unless the general relations of our rainfall to the rain system of the world are considered. The objects of this paper are, therefore, to point out these relations and then to discuss their bearing upon the immediate problems of this State, and to consider the factors of our water supply.

The rainfall of the globe is principally distributed in three zones; these belt the earth near the equator and about in latitude 50° N. and 52° S. These zones are generally designated as the Equatorial and the North and South Temperate rain belts. Between those of temperate latitudes and the equatorial rain belt are the dry or arid belts in the latitude of the tropics of Capricorn and Cancer. The positions of the zones of rainfall and of aridity are better defined on the westerly shores of continents than on their easterly shores.

*Manuscript received January 7, 1902.—Secretary, Ass'n of Eng. Socs.

This is due to the conservative influences of the oceans, which temper the winds moving landward from the west.

On the easterly shores of the continents the dry belts are interrupted by minor oblique belts of rainfall, which are determined by warm oceanic currents which impinge against the continents on that shore in equatorial latitudes and turn northeasterly and southeasterly along the shore lines and then easterly across the oceans in the latitudes of the temperate rain belts.

These currents carry with them the heat and moisture which interrupt the continuity of the tropical arid belts on the east shores of continents. The influence of these oblique belts of rainfall are seen in the moist climates of the southeastern part of the United States and of corresponding latitudes in China which are in the same latitude as the arid regions of Southern and Lower California and the Sahara. There are corresponding interruptions on the east coasts of South America, Africa and Australia. In addition to these irregularities, minor ones are imposed by geographic and physical causes.

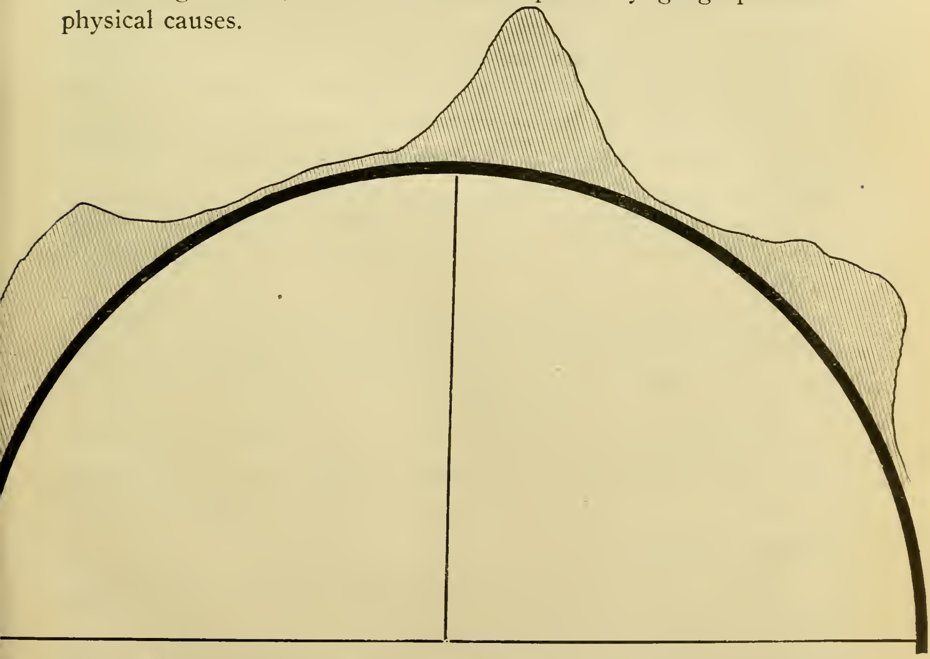


Fig. 1. Mean Annual Rainfall on the West Coast of North and South America (at Sea Level) Projected on the Plane of the One Hundredth Mer. W.

Scale of Section 1 = 100,000,000. Scale of Rainfall 1 = 200.
Data from Plate 18, Atlas of Meteorology. J. G. Bartholomew, F.R.S.E.

Fig. 1 illustrates the distribution of rainfall at sea level on the west coast of North and South America.

It will be observed that there are three distinct maxima and two minima. Similar curves are obtained through the middle of the Atlantic Ocean on the 30th meridian west of Greenwich, on the west coast of Europe and Africa on the meridian of Greenwich, and through the continents of Europe and Africa on the 20th meridian east longitude.

The equatorial rainfall in all of these is displaced a few degrees northerly, due to the greater amount of energy received north of the equator in the longer summer of the northern hemisphere and to the fact that the lower specific heat of the land hemisphere draws toward it currents of air which carry northerlv across the equator some of the moisture and heat received in the southern hemisphere. This makes the north temperate arid belt narrower than the corresponding south temperate belt by about five degrees.

These belts of rainfall and of aridity are persistent over land and sea, and move with the vertical sun to their northerly and southerly positions. This movement may carry them from sea to land, or *vice versa.* These positions and movements, as far as present data reveal them, are as regular in the water hemisphere of high specific heat as they are in the land hemisphere of low specific heat, and these movements would apparently be as regular were the positions and relative areas of land and water to change places.

In order to distinctly show the effect of the vertical sun in shifting these belts, the vertical rays will be followed through a season.

On the 1st of September the sun is vertical over latitude 8° north. By December 1st it has moved to 22° south, passing the equator on September 21st, the autumnal equinox, and moving through thirty degrees of latitude.

From December 1st to March 1st it moves from 22° south to $23\frac{1}{2}$° south and back to 8° south, reaching the winter solstice on December 21st, and in this period moving through seventeen degrees of latitude.

From March 1st to June 1st it moves from 8° south to 22° north, or through thirty degrees of latitude, and crosses the equator on March 21st, the vernal equinox.

From June 1st to September 1st it moves from 22° north to $23\frac{1}{2}$° north and back to 8° north, or through seventeen degrees of latitude, reaching the most northerly latitude on June 21st, the summer solstice.

These oscillations of the zone of vertical rays and of the zones of maximum atmospheric absorption of solar energy, by reason of

the obliquity of the rays, cause corresponding oscillations of the rain and dry belts of the globe, and these belts follow the above described movements with great regularity; the summer being the period of maximum northerly extension of all rain belts, and the rain belts invade the dry regions on their northerly and desert those on their southerly edges; the winter is correspondingly the period of maximum southern extension of all rain belts where they encroach upon the dry belts on their southerly limits. The spring is the period of rapid movement northerly and the autumn of rapid movement southerly of all belts.

Were these movements absolutely exact, or were there no slight variations in them, the rainfall in any particular locality would be more regular than it is. Owing to comparatively slight variations in these movements, marked variations in seasonal rainfall occur. Thus, we in California are between the north temperate and the equatorial rain belt. When, from some as yet unknown cause, the north temperate rain belt shifts a little farther south than usual, we have winters such as those of 1861-2, 1867-8, 1887-8 or 1889-90, when the rainfall was far above, or even double, the average.

Again, as in 1850-1, 1863-4, 1876-7, 1897-8, 1898-9, the north temperate rain belt did not extend as far southerly as usual, and these seasons were deficient in rainfall, falling as low as one-third the average.

These marked variations may be otherwise accounted for:

First. There may be a contraction of the zone over which the rainfall is distributed, giving a deficiency in regions situated as is California, on the edge of one of these zones.

Second. There may be actual variations in evaporation; and precipitation, being a direct function of evaporation, adjusts itself to these variations.

Third. The amount of moisture in the atmosphere being dependent upon its temperature, a year during which a decrease in mean atmospheric temperature occurs must be one of increased precipitation, and when a slight rise occurs in the mean temperature of the atmosphere its capacity to retain moisture increases, and hence a minimum precipitation may follow.

There are, however, no data upon which to rest these explanations, and the one given is both more probable and more in harmony with the facts so far known.

From this brief presentation of the subject, it is seen that the variations in our seasonal rainfall and our change from wet to dry seasons is a part of the rainfall system of the globe.

The exact cause of the seasonal changes is well known, although the mode of action is not fully understood. The cause or causes of the irregular variations are more obscure, and are practically unknown, although their results are of vast importance to the human race, causing widespread losses in many branches of industry and, in extreme cases, severe famines.

In no part of the world are these irregularities of more comparative interest than in California, for here we depend not only upon direct rainfall, but many industries, other than agriculture, depend upon artificial water supplies stored or developed at great expense. When, therefore, two or more years of deficient rainfall occur, the reliability of a given supply is severely tested, sometimes beyond a safe limit. The reliability of a supply and the exact limits to which it may be depended upon for domestic purposes, or for furnishing light or power, become, therefore, a problem of prime importance, to which the highest skill and best judgment of the engineer must be devoted in order that the works he plans may serve their purpose.

The position of California with reference to these rain belts controls its rainfall, and their movements determine our wet and dry seasons. This State lies between the north temperate and the equatorial rain belts, or across the dry belt between these two rain belts. The most southerly and extended rains of the north temperate rain belt just reach our northern border in summer, and during this same period the most extended and northerly rains of the equatorial rain belt reach into the mountains of San Diego County. These are the sonora or summer rains of Northern Mexico.

In the winter the north temperate rain belt moves southerly and the more extended rains of the season cover the entire State, and those of less extent are confined to the region north of Tehachippi.

These movements give Northern Mexico its wet summer and dry winter and give California a rainless summer and a wet winter, with corresponding changes in the southern hemisphere.

It is thus seen that our apparently peculiar climatic conditions are part of the great systems of rain and arid zones which belt the globe and are fixed by cosmic laws.

We will now consider how these, with other factors, control our water supply.

THE FACTORS OF WATER SUPPLY IN CALIFORNIA.

The factors which enter into the water supply of a given source are three: First, the area drained; second, the ratio of precipitation thereon, and, third, the rate of run-off.

Of these the first, *area drained,* is fixed by natural lines and cannot be varied except at the expense of adjacent areas; the second, *precipitation,* is variable from season to season, and can be measured with more or less accuracy, but is entirely beyond human control; the third, *rate of run-off,* is largely under human control, and in small areas of a few scores of square miles can be completely controlled, and over very large areas can be very sensibly modified. Man, through ignorance, cupidity or recklessness, has in numberless instances so augmented this factor that he has converted vast areas of orchards, fields and gardens into a desert and reduced prosperous and happy communities to want and degradation.

The accompanying map of the State shows the general relation of these factors in all the principal rivers and streams of the State.

This map is made from the most reliable data obtainable. The areas are based on the work done by the State Engineering Department. The curves of mean annual precipitation are made from the records of 363 stations, some of which are very meager, but these, by a comparison with adjacent stations, have been given that weight which the writer's knowledge of the State appears to justify. From the data available these curves are probably as accurate as any which can be drawn. The range of rainfall which they represent for any given area will probably vary as follows: A maximum may be double the mean, and a minimum may be one-third the mean.

Over the extreme period of observation, namely, fifty years, it may be said that one-half the seasons have given precipitation about equal to that indicated by the curves; one-seventh have been about the minimum, and one-seventh between the minimum and the mean, and the remainder above the mean, the maximum above indicated having been reached twice. Two, or even three, seasons, which fall very materially below the normal, may occur, whilst it is not generally the case that two very wet seasons follow one another.

The mean rate of rainfall, whilst a guide to the engineer in certain broad generalizations, cannot be entirely depended on except in the case of small areas from which the entire run-off of a wet year can be stored to tide over seasons of deficient rainfall. The storage capacity in this case must be sufficient to hold the maximum, and not the mean, run-off from the tributary drainage

area. This factor is very greatly influenced by elevation, increasing on the most exposed portion of the Sierra, as shown on the accompanying section, Fig. 2. The line along which this comparison is

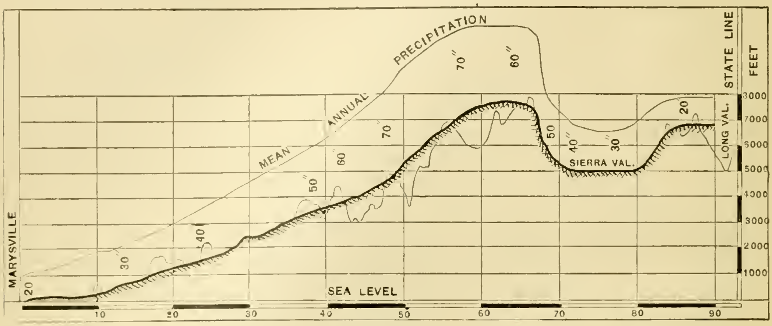


FIG. 2.

made extends northerly across the Sierra from Marysville to Sierraville. At the former locality the mean elevation is less than 100 feet, and the mean annual rainfall is about 20 inches, increasing gradually, to the summit of the Sierra, sixty miles distant, and at an elevation of 8000 feet, to 70 inches, or at the rate of about 6 inches per 1000 feet of increase in elevation. Upon reaching a maximum near the summit, it decreases to 25 inches in Sierra Valley at an elevation of 5000 feet, and still farther decreases to less than 10 inches over the plains of Nevada.

It is thus seen that this factor—precipitation—has within certain limits a greater comparative value as the area drained is elevated, being three and one-half times greater at from 6000 to 8000 feet than at sea level. This comparative value is still farther increased by the temperature, for at this elevation the precipitation is principally snow, which, by slow melting, controls to a very large extent the third factor—*rate of run-off*. This factor is dependent upon several conditions: (a) The character and extent of vegetation, (b) the temperature and rate of melting of snow, (c) the depth and nature of the soil. These three sub-factors of the rate of run-off interact on one another so as to complicate the ultimate result.

The distribution and occurrence of forest and brush on the watersheds of the State is shown on the accompanying map.

These data are taken from the data published by the State Forestry Commission, by the United States Geological Survey and such other minor sources as the writer was able to obtain.

The effects of variations in this factor are shown in the shape and character of the flood channels from different areas. If one

finds the barranca-like channels of the southern part of the State, he does not need to go to the mountain drainage area to find out whether it is wooded or not, and he knows that the rate of run-off is large. Again, if he knows that the drainage area of a given stream in Mendocino or Humboldt County is 200 square miles and finds that its flood-water section and channel is small, he knows at once that this 200 square miles is densely wooded and that the third factor—rate of run-off—is low. If, however, he goes to Lake, Napa, Shasta or other county, and finds the normal flood channels changing their form to the barranca type, he knows at once that the watershed is being denuded and the factor rate of run-off is increasing and that water, the lifeblood of every industry of our State, is being wasted, not for a year, but for centuries to come, and that the fertile fields at the bases of these mountain drainage areas are doomed to become deserts unless the destruction of forests and brush be stayed.

CONTROL OF THIS FACTOR.

This being the only one of the three great factors of water supply which man can control, the modes of control become interesting and important studies.

This control is effected naturally where the precipitation is in the form of snow, the rate of accumulation and melting of which can be observed and to a certain extent utilized. The best data which the writer is able to give are presented on the following diagram, the data for which were furnished through the courtesy of Mr. W. F. Englebright, the chief engineer of the South Yuba Canal Company.

This diagram, Fig. 3, shows the rate of accumulation, depth and rate of melting snow at Lake Fordyce for several seasons. This lake has an elevation of 6500 feet above tide level, and is in a region over which annual precipitation in melted snow is 70 inches.

The variation in depth of snow in different seasons and the effect of late cold seasons is distinctly shown.

Snow begins to accumulate late in November and reaches its maximum depth of packed snow in March. The lower readings on the gauge rod, following higher readings during the winter months, generally indicate a packing of the snow. Melting begins in March and continues quite regularly until the middle of June or early in July. Short storms during April and May cause slight effects in the curve which resumes a parallel line. A series of cold and heavy storms in April, 1896, caused the snow to last until

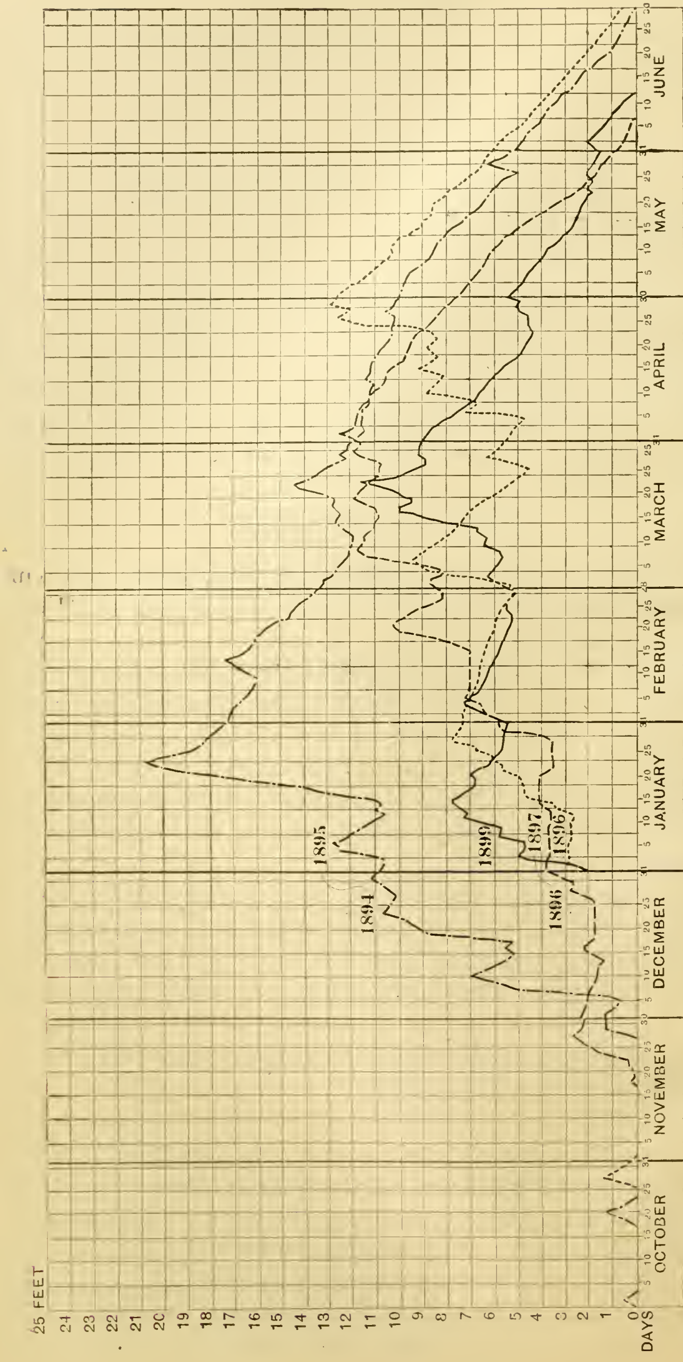


FIG. 3. DIAGRAM SHOWING DEPTH OF SNOW AT LAKE FORDYCE.

(From Data furnished by W. F. ENGLEBRIGHT, Chief Engineer South Yuba Water Co.)

July 5th, whilst the clear, warm spring of 1897 caused it to disappear on the 7th of June.

By means of daily reports by telephone, the chief engineer of the company is enabled, through diagrams upon a larger scale, to approximate during the latter half of April to within a few days of the duration of the snow supply and the beginning of the draught on reservoirs.

Data and studies of this kind are highly valuable, and suggest the importance of stations above the snow line as a means of determining the volume of snow storage available in different seasons and the ratio between the volumes stored by snow and by reservoirs. The discharge of the streams is maintained during the spring and for one-half the summer months by snow and the measure and rate of this discharge can be reasonably foretold by daily readings of properly situated gauges.

This factor is still farther controlled by two processes entirely under human control, namely, reservoirs and forests. The comparative value and efficiency of these have been studied for one of the great drainage areas of the State, namely, Yuba River. T'.:s drainage basin has three principal sub-basins, the North, Middle and South Forks, which present excellent conditions for this comparison.

The basin of the North Fork is comparatively well woc ' ' and has comparatively few storage areas. The basin of the Sc Fork is comparatively lightly timbered and the timber much destroyed, and has remarkably large storage areas, whilst the basin of the Middle Fork is intermediate in character as well as in position.

ARTIFICIAL STORAGE FACILITIES ON YUBA RIVER.

The natural facilities for the storage of storm waters are particularly favorable in the upper third of the drainage basin of the South Fork. The demands for large volumes of water under high pressure to operate the mines in the middle and lower portions of its drainage basin and for those on Bear and American Rivers were met by the construction of large and expensive canals and storage reservoirs:

Storage is had in the following reservoirs:

Name of Reservoir.	Elevation.	Area in Acres.	Capacity in Gallons.	Cost of Dam.
Meadow	7,515 ft.	300	1,275,000,000	$75,000
Stirling	7,200 "	100	340,000,000	20,000
White Rock	7,000 "	80	255,000,000	5,000
Peak Lakes, three	6,900 "	150	1,275,000,000	......
Fordyce	6,500 "	474	5,950,000,000	300,000

Name of Reservoir.	Elevation.	Area in Acres.	Capacity in Gallons.	Cost of Dam.
Lost River	7,000 ft.	...	85,000,000	......
Fall Creek Lakes, six....	7,000 "	171	1,020,000,000	......
Spaulding	4,846 "	215	2,125,000,000	$50,000
Summit Lake	6,800 "	400	1,938,816,000	30,000
Bear Valley Reservoir....	4,400 "	60	145,411,200	8,000
		1,950	14,409,227.200	$478,000
		3.05 sq. miles.	1,921,230,293 cu. ft.	

The aggregate area of these reservoirs is 3.05 square miles, which is filled to an average depth of 22½ feet, thus giving storage for about 12 per cent. of the mean annual precipitation upon the tributary area, the remainder going to waste and to swell the floods which devastate the valley. It is possible, by raising the dams and enlarging the canals, to utilize another considerable fraction. The conditions favoring the conservation of water on the upper one-third of the drainage basin of the South Fork are far more favorable than in the lower two-thirds or those on the other forks.

Upon the upper portion of Cañon Creek (a tributary of the South Yuba) the Eureka Lake, Yuba Canal Company and the North Bloomfield Gravel and Mining Company have a system of storage reservoirs as follows:

Name.	H. W. Area, Acres.	Top Height, Feet.	Top Length, Feet.	Cost.	Barometrical Elevation, Feet.	Catchment Area, Acres.	Capacity in Cubic Feet.
Bowman	500	100	425	$151,521	5,450	12,093	930,000,000
Sawmill Flat	80.6	39.2	...	Total amount expended on the first seven dams and reservoirs is $246,000.	5,780	.....	2,000,000
Shotgun Lake	26.2	10	...		6,410	.....	3,423,816
Island "	48.8	12.8	...		6,690	.....	23,027,558
Middle "	11.2	12	...		6,460	.....	2,395,800
Crooked "	10.3	3	...		6,510	.....	1,600,000
Round "	8.1	11	...		6,590	.....	2,906,630
Fall Creek	..	...	...	......	6,690	.....	....
Jackson Lake......	20	5	...	......	5,410	.....	15,000,000
Faucherie "	90	21	550	8,000	6,060	3,262	58,000,000
Weaver "	83.5	21.8	...	......	....	.....	150,000,000
Eureka "	337.3	68.2	250	35,000	6,480	3,170	661,000,000
							1,849,354,804

The drainage tributary to these reservoirs is 28.4 square miles, which receives a total precipitation, during an average year, of 4,589,481,600 cubic feet, of which 1,849,354,804 cubic feet is stored, or between one-third and one-half the mean annual precipitation.

MIDDLE YUBA.

On the Middle Yuba there are no reservoirs storing water at the present time. The only reservoir area of any importance is the Rudyard or English Reservoir, which has not been in use since

June, 1883, at which date the dam failed. Its possible capacity is 650,000,000 cubic feet.

Weaver Lake is on the watershed of the Middle Yuba, but its catchment area is not large enough to fill it, so it is supplied from the Eureka Lake Company's ditch, from Cañon Creek (a tributary of the South Yuba), and is included in the previous list.

At Milton there is a reservoir site with an estimated capacity of 28,000,000 gallons. The total storage on the Middle Yuba may be considered 678,000,000 cubic feet.

On the North Yuba there are the following small lakes:

Name.	Low-Water Area.
Upper Sardine	38
Lower "	40
Young American	9
Volcano	2½
Packer	7
Saxonia	2½
Deer	5
Upper Salmon	30
Lower "	50
Hawley	11
Spencer Lakes, two	16
Sundry small lakes, five (not named)	27
Deadman's	3
	241 acres.

These might be developed to an aggregate storage capacity of 500,000,000 cubic feet.

But, assuming that artificial storage on the North and Middle Forks could be developed to a capacity equal to that on the South Fork above Lake Spaulding Dam, there would then be in service an area of 6.8 square miles, at an average depth of 26.4 feet, or 5,692 million cubic feet. The mean annual precipitation upon the drainage basin of the Yuba River is 170,829 million cubic feet.

The total ultimate artificial storage is less than 3 per cent. of this precipitation, which could hardly be recognized in a gauging of the total run-off and would be inappreciable in a wet year. Furthermore, in the storage of water for industrial purposes the uncertainty of the character of the seasonal rainfall makes it prudent and desirable to permit the reservoirs to fill during the earlier rains, and not leave the possibility of husbanding a supply to the uncertainty of succeeding rains. Hence it generally happens that, when the heavy storms of the late winter and spring months occur, these storms find the reservoirs full, and the flood wave passes down without being diminished by the capacities of the reservoirs.

This is true only to a limited extent of reservoirs above the snow line, for in these cases the snow constitutes a reservoir of far greater capacity than is ordinarily obtained behind dams. It also happens, in late warm rains or rapid melting of snows, that reservoirs are already full and that the reservoir capacity does not diminish the flood volumes. It would appear, therefore, that, however useful and even essential reservoirs may be for domestic and industrial purposes, they cannot be relied upon, except under exceptional circumstances, to decrease the height of late winter and spring floods.

THE INFLUENCE OF FORESTS IN LOWERING THE RATE OF RUN-OFF.

We have now to consider the second mode of checking the rate of run-off, namely, the preservation and extension of forest and brush-covered areas.

In the study made for the Agricultural Department, the following comparative data were made available:

On the South Fork of the North Fork there is a watershed area of 139 square miles, which was gauged on September 19, 1900, after three successive seasons of deficient rainfall, and gave a minimum run-off of 113 second feet, or 0.8 second feet per square mile. This area is well covered with timber and brush, and in 120 days gives a minimum run-off of 1,441,152,000 cubic feet, which is 75 per cent. of the low-water flow of the entire drainage basin of the Yuba River.

On the South Fork, above Lake Spaulding, there is a watershed of 120.9 square miles. The run-off of this area is practically nothing for 120 days each year, due to the absence of forests and brush. If this area were afforested, and gave a minimum run-off of 0.8 second feet per square mile (as above in the case of the North Fork), the discharge would be 100 second feet for 120 days, or equivalent to 1,036,800,000 cubic feet effective storage capacity, a discharge more than equivalent to three-fourths the storage capacities of all the reservoirs above Lake Spaulding Dam. As the basis of this comparison is extreme low-water discharge, it is safe to assume that by afforesting this watershed the costly and extensive system of reservoirs might be safely drawn upon for double their present capacity. When this reasoning is applied to the entire drainage basin of 1357 square miles, instead of to small fractions thereof, the force of the argument becomes more apparent.

SOLUTION OF THE PROBLEM OF STORAGE OF FLOOD WATERS.

It would appear from the foregoing that the solution of the problem of checking the rate of run-off by storage is not in the


OREGON
PACIFIC OCEAN
NEVADA
MEXICO
MAP OF THE
STATE
OF
CALIFORNIA
SHOWING
THE THREE PRINCIPAL FACTORS IN THE
WATER SUPPLY
(1) - THE AREAS OF THE PRINCIPAL WATER-SHEDS, SHOWN ENCLOSED BY RED LINES, THE RED FIGURES GIVING THE NUMBER OF SQ MILES IN THE AREA.
(2) - THE MEAN ANNUAL DISTRIBUTION OF RAINFALL SHOWN THUS
(3) - THE TIMBER AND BRUSH-COVERED AREAS WHICH CONTROL THE RATE OF RUN-OFF.
TIMBER AREAS SHOWN THUS
BRUSH " " "
—NOTE—
THE FIRST FACTOR (AREA) IS FIXED AND CANNOT BE VARIED EXCEPT AT THE EXPENSE OF ADJACENT AREAS.
THE SECOND FACTOR (RAINFALL) IS NOT UNDER HUMAN CONTROL AND IS VARIABLE FROM SEASON TO SEASON.
THE THIRD FACTOR (RATE OF RUN-OFF) IS LARGELY UNDER HUMAN CONTROL. BY EXTENDING AND PROTECTING FOREST AND BRUSH-COVERED AREAS THE RATE OF RUN-OFF AND THE FLOOD WATER DISCHARGE ARE DECREASED AND THE LOW WATER DISCHARGE INCREASED AND PROLONGED. BY THE DENUDATION OF FOREST AND BRUSH-COVERED AREAS THE RATE OF RUN-OFF AND THE VOLUME AND DESTRUCTIVENESS OF FLOODS ARE INCREASED AND THE LOW WATER DISCHARGE IS SHORTENED AND DECREASED.
EXTREME RANGE OF RAINFALL.
THE PROBABLE MAXIMUM YEARLY RAINFALL IS ABOUT DOUBLE, AND THE PROBABLE MINIMUM IS ABOUT ONE THIRD THAT SHOWN BY THE MEAN ANNUAL CURVES OF RAINFALL GIVEN ON THIS MAP
12 0 12 24 36 48 60 MILES
50 100 KILOMETERS
COMPILED FOR
THE CALIFORNIA WATER AND FOREST ASSOCIATION
BY
FLETCHER F S KELSEY
DIRECTED BY
MARSDEN MANSON C.E.
DATA OBTAINED FROM THE FOLLOWING SOURCES.
DRAINAGE AREAS FROM THE STATE ENGINEERING DEPARTMENT.
RAINFALL FROM U S WEATHER BUREAU 216 REC STATIONS
RECORDS BY J B LIPPINCOTT C.E. 88 " "
STATE ENGINEERING DEPT DATA 88 " "
387
FOREST & BRUSH AREAS FROM REPORTS OF THE CALIFORNIA STATE BOARD OF FORESTRY 1886 & 1888, AND U S GEOLOGICAL SURVEY REPORTS & MAPS OF 1898.
SEPTEMBER 1900
GLENN
YOLO
SOLANO
CONTRA COSTA
STANISLAUS
MERCED
SAN BENITO
KINGS
KERN
SAN BERNARDINO
RIVERSIDE
SAN DIEGO

It would appear from the foregoing that the solution of the problem of checking the rate of run-off by storage is not in the

retention of a small percentage of the storm waters behind dams, but in checking the rate of run-off over the entire watershed by the systematic protection and extension of forest and brush-covered areas.

REVIEW.

The three principal factors of water supply, *area of watershed, precipitation thereon, and the natural condition controlling the rate of run-off,* are presented for all the principal streams of the State in the accompanying map.

The first two of these factors can be measured, studied and compared, but cannot be controlled nor materially affected by human agency. The third, *rate of run-off,* is largely under human control, and every effort should be put forth to direct public attention to the importance of checking it. No broader nor more comprehensive problems come before our profession than those relating to the conservation and use of water, and the skill and thoroughness with which our mountain water supplies are conserved will fix for the remotest future the metes and bounds of the civilization we are striving to establish. Reservoirs alone, as a means of checking the rate of run-off, serve only for a time. Unless the watersheds which fill these be protected, these reservoirs silt up or are filled with sand and gravel. Systematic forestry only will permanently check the rate of run-off and conserve this factor of water supply. Where this is neglected, history and nature record no law more inflexible, no effect more certain, than that poverty and degradation follow upon the destruction of mountain forests.

PERSONAL EXPERIENCES IN THE CONSTRUCTION OF A LANDING PIER FOR THE OCOS RAILWAY, GUATEMALA, C. A.

By Charles List, Civil Engineer.

[Read before the Technical Society of the Pacific Coast, March 6, 1903.*]

The maintenance of an ocean pier, the property of the Ocos Railroad, formed part of my duty during a period of five years. An account of the history and construction of the pier, some of the experiences gained, and deductions therefrom, might be of interest.

Ocos is an open roadstead, situated on the Pacific Coast of Guatemala, C. A. The beach at this locality slopes down gently into the sea. It is made up of sand of almost uniform size; depth not known. A heavy swell, causing high-breaking surf, prevails almost all the year round. Severe storms occur frequently from

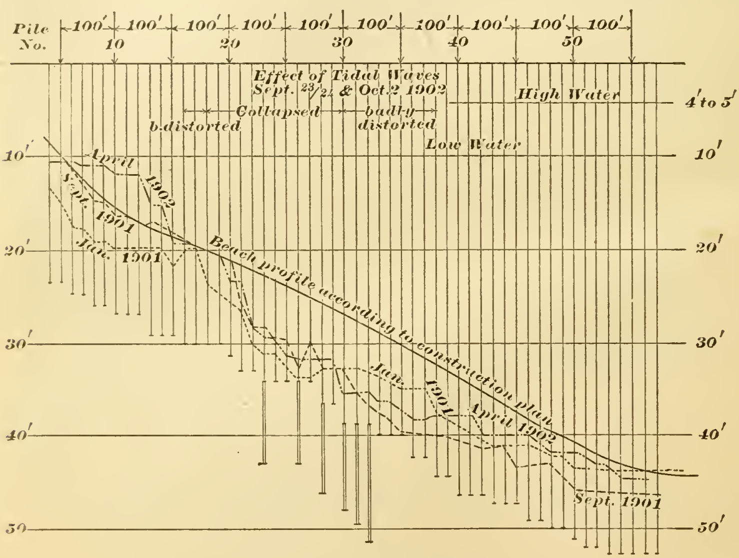


Fig. 1. Ocos Pier Profile.

June to October, and, in addition, there are currents produced by two rivers emptying into the ocean 1 mile south of the pier, especially during the rainy season, June to October, causing a constant shifting of the sand on the bottom of the sea. All these circumstances combined make the site of this pier a most undesirable one.

The pier extends 1200 feet from the beach into the open ocean. Of this total length about 800 feet are outside the surf line. It stands some 10 feet above high water; difference of level between low and high water, 5 to 6 feet. Steamers lie at anchor 500 to

*Manuscript received April 6, 1903.—Secretary, Ass'n of Eng. Socs.

1000 yards from the pier end; traffic between pier and steamer is carried on with lighters of a maximum capacity of 30 tons.

The piles of the pier are arranged in bents set 20 feet apart, each bent consisting of three piles 8 feet from center to center. Tie-rods join the piles above low water plane, lengthwise and crosswise. (See Figs. 2, 3 and 4.) The floor beams carry two

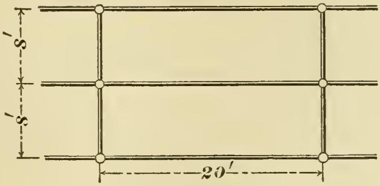


FIG. 2. PLAN.

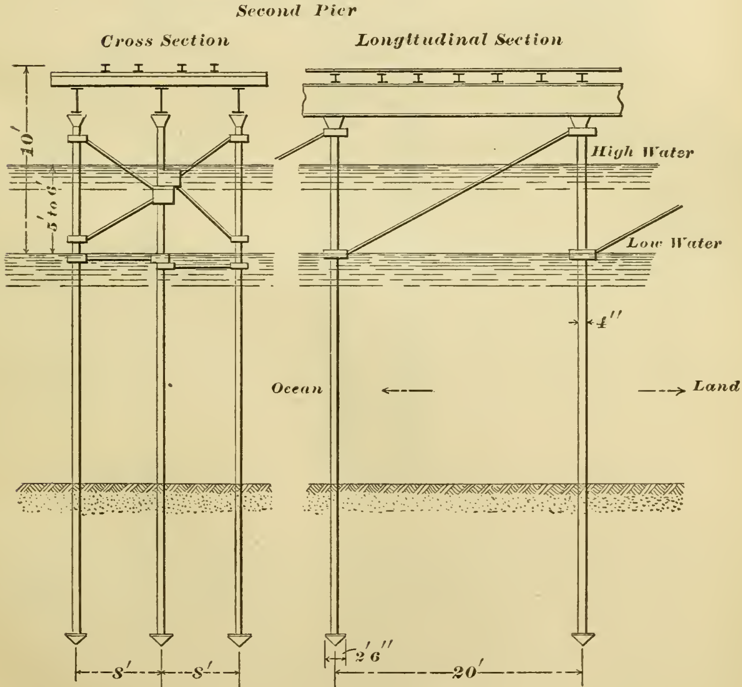


FIG. 3. FIG. 4.

narrow-gauge railway tracks. On the sea end, for a length of 160 feet, the pier is widened to thrice its width and roofed over where the hoisting engines and windlasses are wanted, two on each side.

The first pier was constructed from 1883 to 1885, the piles consisting of wrought-iron sectional cylinders, 4 inches outside

diameter, formed of four segments riveted together lengthwise. (See Fig. 5.) The piles had disk-shaped cast-iron shoes, 2 feet diameter. By means of a hole, ending in the point of the shoe and pipe connection, the piles were jetted down into the sand with a 6 x 8-inch pump. After being put in position they were filled up with concrete. After a few years of existence the piles got loose, the pier became distorted, and the whole construction was in imminent danger of collapse. The party then in charge of the pier contended that this condition of affairs was due to the shifting of the sand on the bottom of the sea, which abraded the pipe walls, compelling the riveted flanges, also in weakened condition, to sustain the structure. To remedy this, wrought-iron sleeves,

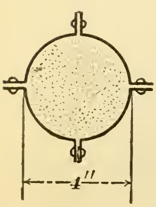


Fig. 5.

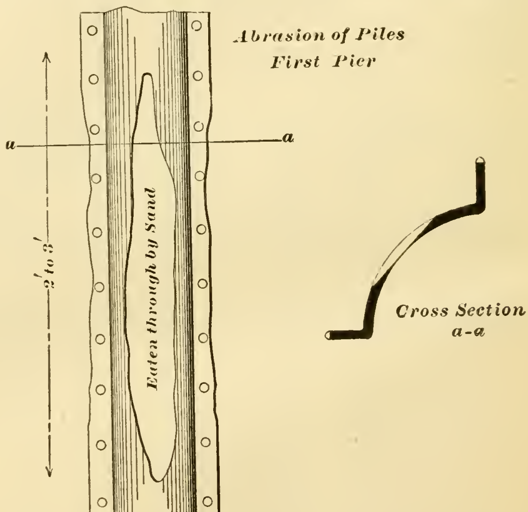


Fig. 6.

3 feet long, 1½ inches thick, were ordered, and it was the intention to have them put on the piles at the injured localities by divers. While the sleeves were being made and forwarded, the owners had agreed upon the construction of a new pier, consisting of round, solid steel piles 4 inches in diameter, connected by strong bracing. This new structure was erected from 1893 to 1896 on the same spot, so as to leave the floor construction undisturbed. The shoes of the new piles were larger, 2½ feet in diameter, and, in order not to get entangled with the old existing piles, the new ones were sunk at a distance of some 3 to 4 feet from the former.

When I took charge, in 1897, the pier was just finished and in very good condition, but soon the old trouble commenced again. The piles sank down and the whole pier got out of level and align-

ment. Repeated soundings revealed the fact that the currents were continually carrying away the sand at the bottom. How this shifting had been going on will be seen from the sketch, Fig. 1, showing the changes in 1901 and 1902, also the original line of the bottom according to the construction plans. The piles were cer-

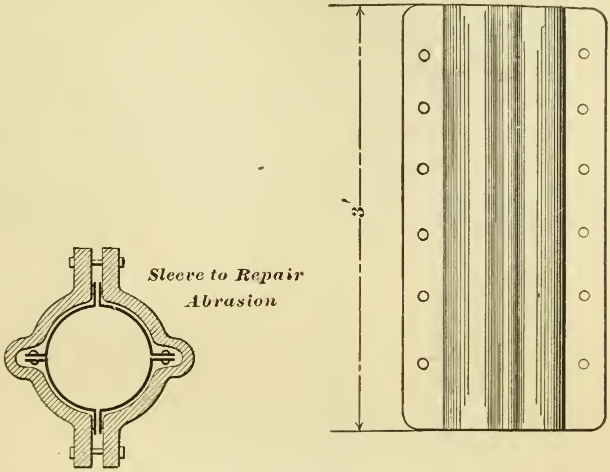


FIG. 7.

tainly not sunk deep enough into the sand, as they originally stood only from 9 to 12 feet, instead of at least 25 feet, in bottom. The lack of judgment and foresight is very evident, for the least attempt to investigate into the shifting of the sand in former years would at once have brought out the fact that these movements were

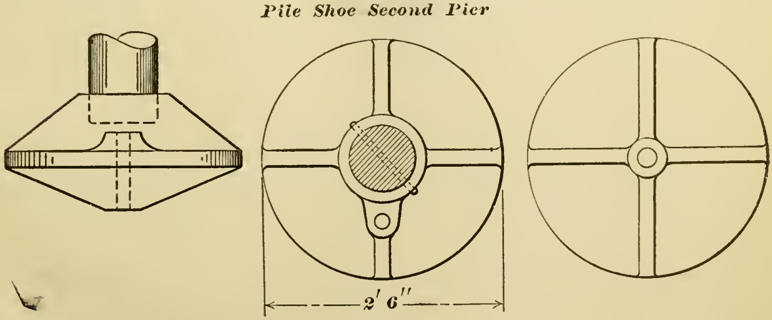


FIG. 8.

insignificant when compared with events not very remote, namely: There are three or four old beach lines distant 50 to 150 feet from the existing shore line, which bear out the statements of old inhabitants as to the locality of former encroachments of the sea on the beach.

The main cause for this erratic movement is to be sought in the river outlets, which, in conjunction with the tidal and littoral currents, are constantly reshaping the outlying sands, increasing a sand bank or bar in one place and decreasing it in another, as is usual in indented coast lines.

Reconstruction of the endangered piles was urgent. Some of them, in 1900, stood only 3 feet in bottom; in 1901 and 1902 worse yet, only 1 foot. But for systematic work with the necessary material no funds for labor were available. I had no other recourse than to use the pieces of the old pier (a big boneyard of them was found on the shore) and drag along with the work with the regular existing gang of piermen, all told four to six men, materially to the detriment of other necessary work.

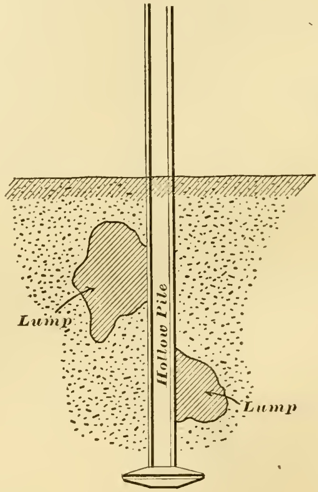


Fig. 9.

In that way 12 piles in 6 bents were sunk 9 to 13 feet deeper. It was very slow and tiresome work. Nevertheless, a few months more would have been sufficient to bring the pier out of immediate danger, when, all at once, work was brought to a sudden stop by the earthquake of April 18, 1902. That shake struck the pier, coming from the ocean, in the direction of its center line. The undulations of the earthquake wave shook part of the poles down into the sand; others were lifted up, for the simple reason that none of the piles were really driven deep enough, so that, after the shake, the pier presented exactly the form of the waves, about 30 yards long and some 6 to 8 inches deep each. A few of the floor-beam connections were broken and the beams thrown off the piles, the pier therefore hanging in the air for quite a distance.

The repairing of this and much other damage caused to buildings and other structures on shore by the same earthquake took up much valuable time. When everything was fairly in order again and work on deepening of the piles was to be renewed, another drawback occurred. The sea began to break away the beach; workshops and warehouses had to be moved farther inland—as

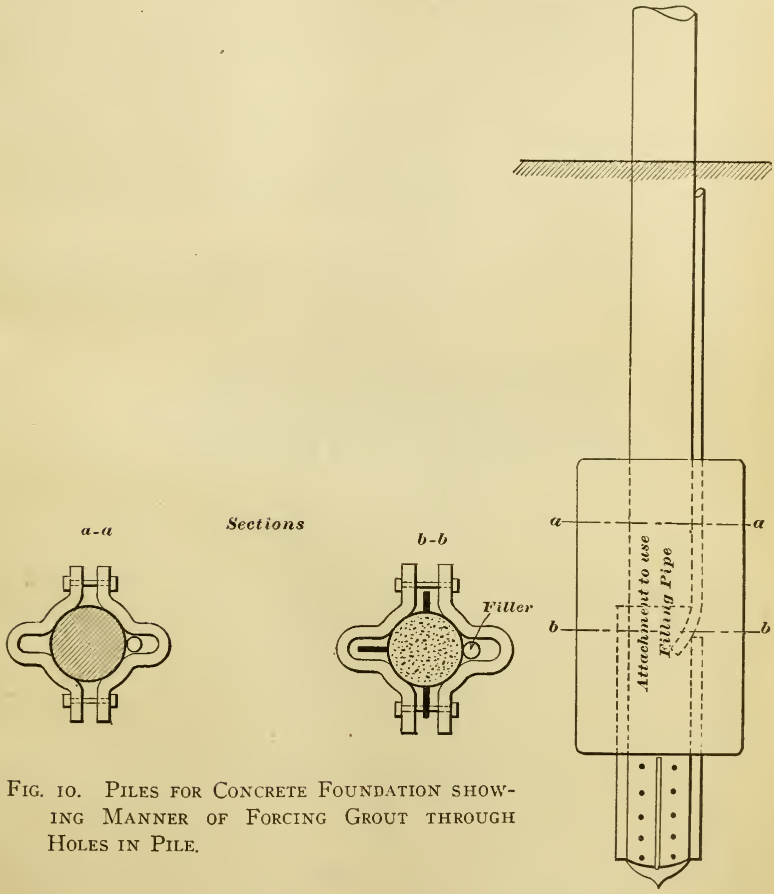


FIG. 10. PILES FOR CONCRETE FOUNDATION SHOWING MANNER OF FORCING GROUT THROUGH HOLES IN PILE.

much of them as the sea had not carried away altogether. The pier was getting disconnected from the land, provisional supports had to be put in to keep the traffic open, people began to get frightened, and most of the workingmen left the place. At last, on September 23 and 24, 1902, a severe storm, earthquakes and tidal wave distorted the pier completely, and created an open gap of 150 feet between the pier and the land by breaking away that

much beach; and a second tidal wave, on October 2d, caused a complete collapse of a section in the middle of the pier 240 feet long, carrying part of the heaviest iron a distance of 3 miles along the coast, where it could be seen afterward on the beach.

In this shape the pier stands to-day. In the conclusion of this history it must be said that, while the repairing of all this damage would not amount to much in any active modern community, it is a different thing in a country so far out of reach. No skilled men for this work were to be had; all were common "peones," the foreman, a native, being the only fairly reliable person. Even tools were scarce, and after the earthquake of April 18th an accumulation of evils and reverses prevailed, such as continued earthquakes, inroads of the ocean, tidal waves and volcanic eruptions, which made things decidedly disagreeable and the prosecution of the work at times impossible,

The work of setting the piles deeper was done in the following manner: After disconnecting the pile from its tie-rods and floor

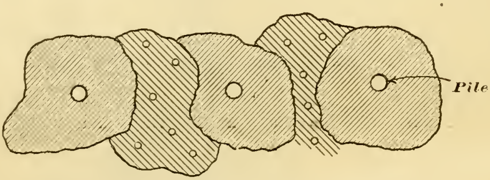


FIG. 11. CONCRETE PILE FOUNDATION.

beams (a slow process, as everything was rusted together), it was hauled up out of the water; the shoe was cleaned; the pressure pipe, $1\frac{1}{2}$ inches in diameter, was inserted into the shoe, and the pile was lowered again and jetted into the sand with the pump. The splicing of the extension piece was done on top of the pile, employing for that purpose the unused sleeves ordered for the repair of the abraded piles. Considerable difficulty was experienced in the sinking of several of these piles, as many of the piles of the first pier were surrounded by lumps of concrete, caused by cement grout which had escaped through leaks in the riveted seams of the pipes, and thus forming with the sand solid masses of concrete mortar adhering to the pile. It was this that gave rise to the thought of utilizing this means, which nature had pointed out, in the systematic reconstruction of the pier after the earthquake of April 18th.

I had in mind to set the piles 25 feet in the sand, not by the force of the water jet, but by screwing them in. For the lower part of the piles under ground, say 20 feet, the old existing piles

of the first pier were to be used; for the upper part the full 4-inch steel rods. The wall of the tubular pile was to be perforated with conveniently-arranged holes, and on the upper end a sort of nozzle was to be attached, into which a $1\frac{1}{2}$-inch pipe could be inserted, connecting at the other end with a double-acting pump. With the pile in place, cement grout was to be pumped into the tube and forced through its holes into the sand surrounding the cylinder, creating in that way a cement block in and around the pile. The space between the piles of each bent which the grout would not

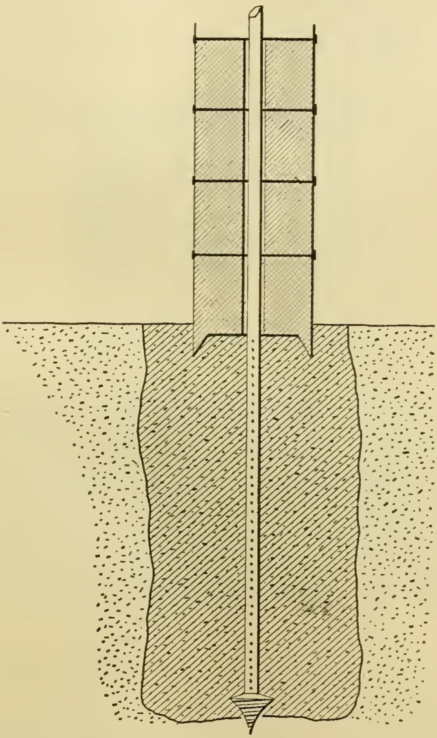


FIG. 12.

reach was also to be converted into concrete by means of a perforated pipe of small diameter, movable, so that it might be inserted in different places and at different depths, the pumping proceeding as described, until the three piles of each bent would stand in a perfect block of concrete.

That it is possible in this way to convert the sand around the pile into concrete is not only conclusively proved by the fact that the mere pouring of cement mortar into the cylinders caused an oozing of escaping cement grout which did form actual concrete

outside of the cylinder, but it is also satisfactorily explained in that the beach sand is of nearly uniform size and free of mud, so that the cement grout could fill the interstices between the individual small grains of sand where it would lodge.

Such a pier foundation, beside offering great stability, would not cost more than one of solid steel rods. It would be, within certain limits, independent of the bearing power of the sand. The skin friction of the pile, so far as my knowledge goes, is a factor not at all definitely established as yet, and would not have to be

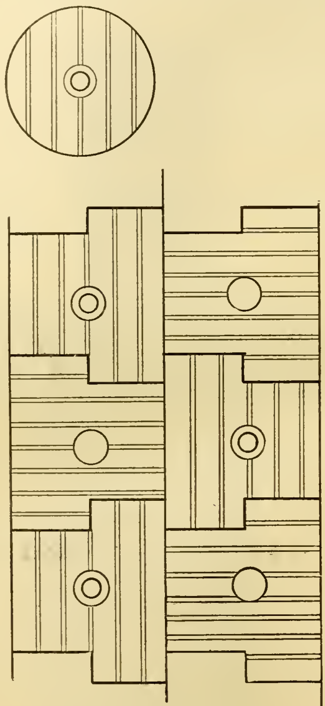


Fig. 13.

taken into consideration. There is practically only one factor which would rule this foundation: it must be carried so deep as to prevent its being washed out.

In conclusion, I wish to say that this foundation may with advantage be adapted to the construction of concrete piles for wharves, or even for sea walls, provided the ground consists of sand and gravel not containing too much mud. Pipes, perforated below ground, would be inserted in the bottom to the necessary depth and the surrounding sand would be converted into concrete as described above. That part of the piles or the sea wall above the sea bottom could be formed by concrete blocks slipped, like

sleeves, over the upper part of the piles. The seams on the outside of the piles or wall could be tightened and all seams and inside spaces filled out by pouring cement mortar from above into all available interstices, in that way making the structure practically monolithic.

I offer this as a method which, under certain conditions, may be found perfectly practicable and available, and, in the discussion of the methods of construction of armored concrete wharves and piers, I beg to submit this suggestion to the Society. You will see that I have sufficient practical experience in this direction to treat the subject from more than a purely theoretical standpoint.

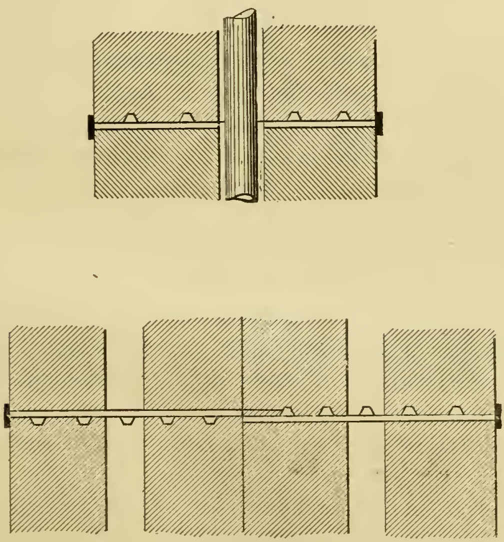


FIG. 14.

Mortar which had oozed through the seams of a cylindrical pile formed, in combination with the surrounding sand, an exterior lump of concrete that clung to the pile with all the tenacity of a barnacle. There seems no good and sufficient reason why, by some simple mechanical process like the one suggested, this feature may not be developed to the extent of surrounding with concrete more or less of the entire portion of the pile that is driven into sand.

To be sure, the method requires sandy bottom, such as is frequent on the coast and with which our military engineers have to deal often enough. In mud, as prevailing in the Bay of San Francisco, it is quite probable that nothing will ever replace the long timber pile that bears the load by its skin friction, and which

may be armored against the ravages of the teredo by encasing it above the bottom. It is extremely doubtful whether, under conditions like these just referred to, a pile built up entirely of concrete could ever be successfully used; that is, so as to compete in cost with one of the same life and efficiency furnished by the protected timbers.

Every locality must be treated in its own peculiar way, and it is left to the engineer to suggest the proper method and means for each individual case.

In anticipation of possible criticisms and objections, I wish to say something about concrete made with salt water and the influence of sea water upon concrete. Years ago I had read about investigations undertaken by cement experts in that line, but, as the corresponding literature was not at my command, I was not able to follow up the subject, so that even at the present day I have no definite knowledge of the results of this investigation.

From my personal experience, acquired in connection with the work described above, I am enabled, however, to testify to the following facts:

1. The concrete lumps accidentally formed around the piles existed since 1883 or 1885. The water employed in mixing the concrete was certainly sea water, as there is hardly fresh water enough for drinking purposes in the whole village. Nevertheless, the concrete is as hard as it could be. It is difficult, for instance, to break the concrete out of the piles which were pulled up about five years ago and which have been lying in the boneyard exposed to the weather ever since.

2. Concrete in a foundation for a railway bridge, made in 1895 with brackish water, and standing in the same water ever since, is to this day of excellent quality, although, to my knowledge, the proportion of cement was rather small and the sand and gravel employed were more or less dirty.

3. I had to fill out seven iron cylinders, 2 feet in diameter and 12 to 15 feet high, with concrete, to form the abutments and center pier of the bridge referred to in No. 2. The necessary cement was not forthcoming in time, and work was about to be suspended, when the foreman called my attention to several hundred barrels of cement which had been abandoned four years before as "ruined by salt water," and had been stored away under the floor of a warehouse having open sides and exposed, therefore, to the moisture of the ground as well as to the continuous spray of the sea. This cement was originally intended for railway work. The sailing vessel which brought it from Hamburg had sprung a

leak, this part of the cargo was considered a loss, and the value of the cement had been refunded by the insurance company. I had opened several of these barrels before, and found their contents solidified almost to stone. Several of these cement blocks I used as foundations for wooden pillars in buildings. The foreman told me that some of the villagers had taken a few barrels away and pounded up the cement and made concrete floors and small foundation walls out of it. I saw them and they were perfectly good. So I decided to do the same thing. The cement was pounded up as fine as possible, mixed with good, sharp beach sand, river gravel and brackish water. After three days the concrete was perfectly hard, the bridge shoes were put on top of the concrete, and when the first train passed over it the whole bridge sank down from 1½ to 2 inches, for the reason that the sharp edges of the cylinders had been pressed into the underlying beach sand. I leveled the bridge up again by putting small steel wedges between some of the bridge shoes and the concrete, and thereafter it never moved until the earthquake of April 18th upset all the cylinders and made the bridge collapse. The concrete to-day is as good as it can be. After this experience, and taking into consideration the scarcity of material, I used all this cement, as far as it was not entirely too hard, in bridge foundations, sometimes mixing it with fresh cement of good quality, but frequently without such addition. Not any of the concrete so produced ever resulted in a failure.

FOUNDATION FOR COAL POCKET AT LINCOLN WHARF, BOSTON ELEVATED RAILWAY CO.

By Robert B. Davis, Member of the American Society of Civil Engineers.

[Read before the Boston Society of Civil Engineers, February 18, 1903.*]

The question of rapid and economic handling of coal for power plants is daily becoming one of vital importance from every point of consideration. The out-of-date methods of transferring coal from vessels to boilers at a cost varying from fifteen cents to twenty-five cents per ton are fast being superseded by up-to-date practice, whereby the cost of handling coal from vessel to boiler is reduced to a figure nearer three cents to five cents per ton.

To have the requisite dockage for coaling vessels, where they can enter direct from the harbor, without the delays and expense incident to passing through drawbridges; to have modern equipment convenient for quickly discharging the vessels and thus avoid the disagreeable factor of demurrage, and to provide suitable storage for coal under such conditions that it may be delivered to the boilers by approved machinery with a minimum amount of labor and expense—all these important considerations influenced this company in deciding to install an up-to-date coal handling and storage plant at Lincoln Wharf, adjacent to the large power station there located. To the writer was intrusted the general layout and design for this plant, subject to the approval of the management, and it is the foundation or wharf under the coal pocket that is briefly described in this paper.

It was decided at the outset that to obtain a pocket of the desired capacity—about 5000 tons—and have it located favorably for the rapid discharge of coal from vessels into same it would be necessary, due to the location of the power station and general layout of the property, to build the pocket over the water, extending same to the Harbor Commissioners' line, and providing a dock 60 feet wide on the south side of the pocket for berthing coal vessels. Owing to the limited length of dock, it could not be planned to move vessels back and forth to bring the hatches under a fixed hoisting tower, and it was, therefore, necessary to figure on movable hoisting towers which travel on top of the pocket for its entire length, thus reaching the various hatches of the vessels. The weight of these towers was necessarily an important factor in considering the total loads on this foundation.

*Manuscript received March 18, 1903.—Secretary, Ass'n of Eng. Socs.

The following loads were considered in designing the foundation:

a. Wharf load under pocket, 350 pounds per square foot.
b. Wharf load outside of pocket, 30-ton coal car.
c. Timber pocket at 4.5 per foot board measure.
d. Pocket roof, 50 pounds per square foot.
e. Coal, 50 pounds per cubic foot.
f. Towers, 80 tons.

From the above combined loads, a maximum loading was obtained, with snow on roof of pocket, pocket filled with coal, towers operating, and wind pressure at 30 pounds per square foot, which gave maximum loads at foot of pocket posts varying from 60 tons to 80 tons for each of the two outer posts and 115 tons to 120 tons for each of the two inner posts, the pocket being constructed with transverse bents of four posts each 13 feet center to center, the bents being spaced 10 feet center to center.

To support these loads safely and economically several schemes were proposed, some of which were studied out in more or less detail, one being a crib bulkhead with solid filling, another consisting of concrete piers supported on piles cut off at low water. Both of these propositions had their respective objections, prominent among which was the expense incident to such construction. A further study was made for a pile foundation, combining in reality a heavily constructed pile wharf, with specially constructed groups of piles to receive the posts of the coal pocket. This last proposition met with the approval of the management, and plans were made on this basis and the construction carried out accordingly.

The foundation was laid out to extend from the Harbor Commissioners' line westerly about 300 feet to a sea wall at the head of the dock, and to have a width of about 66 feet, the coal pocket having a width of 40 feet. This allowed a space about 13 feet wide on each side of the pocket for a standard gauge track for 30-ton coal cars.

A careful examination was made to ascertain the depth of water and nature of the bottom, which had much to do with determining the length of piles to be used and the allowable loads on same.

At the westerly end of the foundation site, along the sea wall before referred to, a depth of water was found varying from 8 feet at mean low water on the south side to about 3 feet on the north side, while along the Commissioners' line the depth varied from 16 feet at mean low water on the south side to about 12 feet on

the north side, the bottom sloping uniformly from the sea wall to the Commissioners' line. These results necessitated dredging the dock to a sufficient depth to properly accommodate steam colliers, or 22 feet at mean low water, which, owing to the natural slope of the bottom after dredging was completed, gave fairly deep water for the outer lines of piles on the south or dock side.

Numerous borings made in the immediate vicinity of the site showed a very good bottom for substantial pile construction. The bottom, while varying somewhat in the nature of the strata at different points, yet on the whole consisted of a fairly stiff blue clay and hard yellow clay extending to a known depth of from 40 to 50 feet.

After carefully considering all the important conditions, it was decided that a penetration of from 20 feet to 25 feet—not considering the upper layer of soft silt, about 3 feet to 4 feet thick—would give ample bearing power for the piles, probably from 15 tons to 20 tons per pile. A maximum load of 12 tons per pile was allowed. In all cases the piles were carefully and thoroughly driven to the satisfaction of the engineer.

The piles were generally driven without shoes, being cut off square at the point. The piles are of first quality oak, varying in length from 45 feet to 60 feet, not less than 7 inches in diameter at the point and not less than 14 inches in diameter when cut off at grade. All timber is long-leaf Southern pine, "prime inspection," excepting the walling timbers and diagonal braces, which are of oak.

The foundation consisted generally of some 30 transverse bents, each about 66 feet long, and spaced 10 feet center to center. In these transverse bents the groups of piles forming foundation for pocket posts are spaced 13 feet center to center, with intermediate bearing piles between these group piles, and also on the north and south sides to support the wharf floor and car tracks. Range points were fixed locating the piles transversely and longitudinally, and by these range lines all piles were driven in their proper position, as called for by the plans. The groups of piles are of two types, according to the loads they support; those receiving the outside posts of pocket consist of 7 piles, 3 under main cap, with 2 outer piles on each side, and staggered with the 3 center piles. The groups receiving the inner posts of pocket with their increased loads consist of 10 piles, 4 under main cap, with 3 outer piles on each side and staggered as before described. The group piles are spaced about 2 feet 6 inches to 3 feet center to center.

After some little experimenting as to the best methods to be employed in driving the group piles and obtaining most satisfactory results as to alignment, it was decided to first drive all piles in same line and under main cap with a water machine. These piles were thus driven, accurately lined up and carefully sawed off to

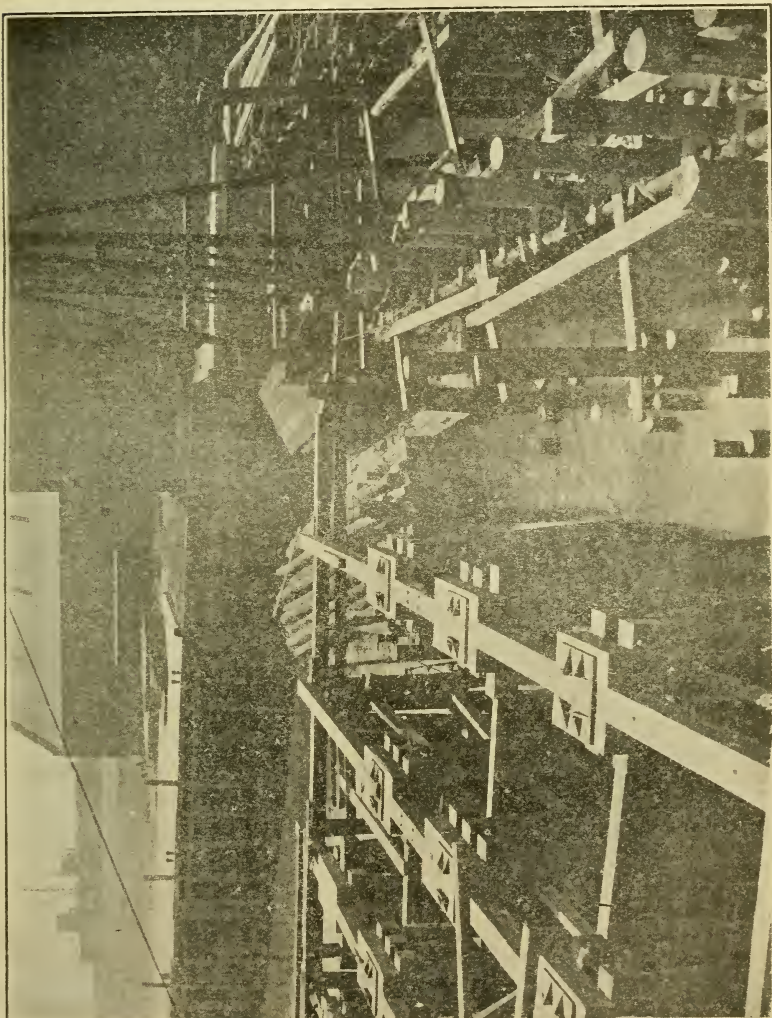


Fig. 6. Footing for Pocket Posts.

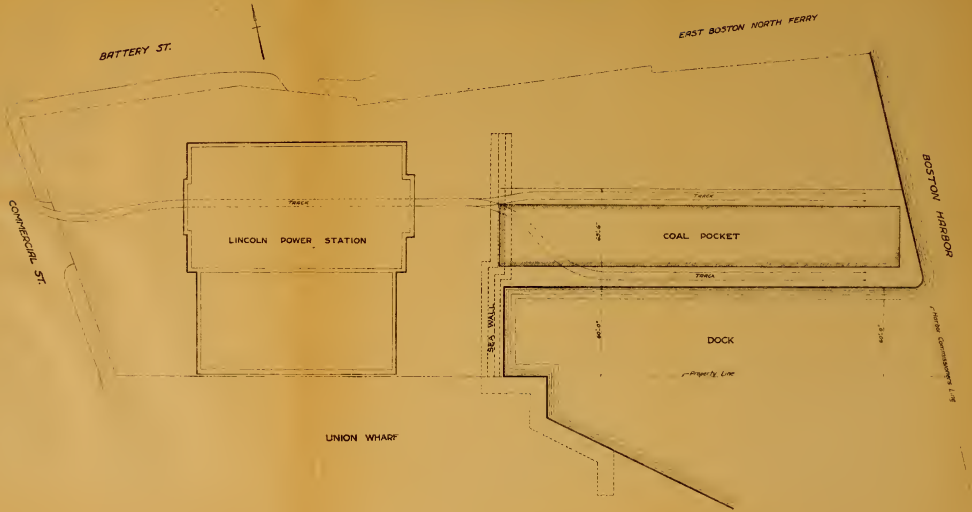
grade. The main cap timbers, 12 inches by 12 inches, were then placed in position on tops of piles, but before securing the same in place oak shim blocks 2 inches thick were placed between pile head and cap, and off center sufficient to clear the 1-inch drift bolts, securing cap timber. The object of these shim blocks will be seen

as we proceed. The main cap timbers are spliced once in their length and at the points and in the manner shown on plans.

After a number of these bents were thus far completed, temporary longitudinal timbers were placed on same to brace them and to accommodate a land machine, which was used to drive the group piles on each side of the piles in main bent. These outer piles were driven at an inclination of 1 foot in 25 feet in order to slightly spread the points and avoid, as far as possible, disturbing the footings of the vertical piles in the main bents previously driven. They were sawed off to a grade 1 foot below that of the piles in the main bent. Corbels 12 inches by 12 inches by 5 feet long were then placed under the main cap, between the piles under same, and secured on top of the pairs of outer piles with 1-inch drift bolts, the 2-inch shim block before referred to allowing sufficient working room to place these corbels in position. After all the corbels required in a bent were in place, the shim blocks were removed and the main caps drifted down securely on the piles, bringing same to a true bearing on the corbels, to which the caps are also secured with 1-inch drift bolts. Auxiliary caps 12 inches by 12 inches by 6 feet long were then placed on tops of corbels on each side of main cap and close to same and secured at each bearing on the corbels with 1-inch drift bolts. This construction furnishes something of a timber grillage, permitting, as far as possible, a distribution of the loads over all the piles in a group. To further assist in distribution of the loads, after the timber work above described was completed, the tops of the main caps and auxiliary caps over each group of piles were truly surfaced off to exact grade and a cast-iron footing plate placed in position to receive the pocket posts. These cast plates are of 1½-inch metal, with necessary webs, and are about 3 feet square. They are secured in position as to alignment by countersunk head bolts. These cast plates were further deemed necessary as the pocket posts are made up of a number of individual timbers, usually three vertical timbers 10 inches by 12 inches, and four batter posts 8 inches by 10 inches, all of which are close together at the foot, making, in reality, seven footings on each cast foot plate. The tops of all bearing piles are cut off to a truly horizontal plane and to exact grade. No blocking or shimming whatever was allowed under cap timber or corbels to bring the same to a true and level bearing.

The tops of all bearing piles were covered with hot dead oil of tar before any timbers were brought to bear on same.

LINCOLN WHARF PROPERTY
BOSTON ELEVATED RAILWAY COMPANY



PLAN OF COAL POCKET FOUNDATION

Between the center lines of piles and the two outer lines of piles in each bent, and extending across same, are secured the waling timbers or horizontal girts of 4-inch by 10-inch oak, of which there are two double lines, one at elevation mean low water and one at

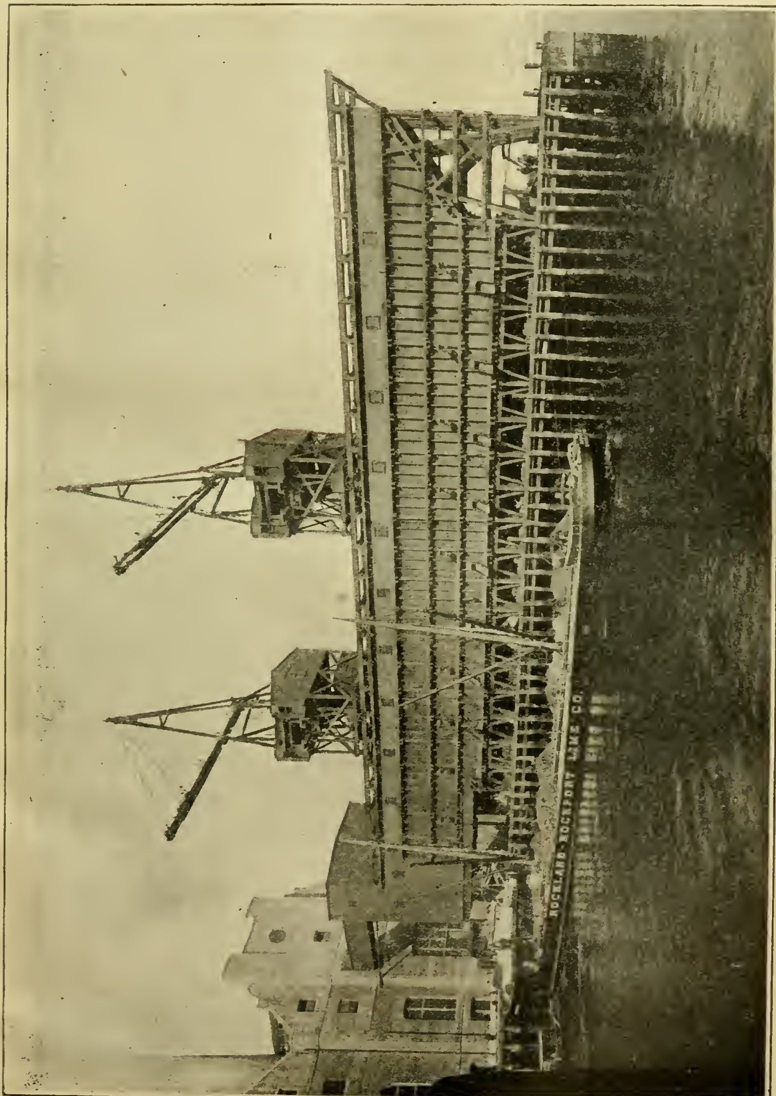


FIG. 7. COMPLETED COAL POCKET.

elevation + 12. These are bolted to each pile in the bent, against which they bear with 1-inch bolts. Diagonal bracing of 4-inch by 10-inch oak is placed across the bents, extending between the upper and lower lines of waling timbers, and securely bolted to the

outside of piles of each group. There are three panels of diagonal bracing in the length of a bent. On the dock side spur piles are placed against the outer and central piles of the outside groups. Spur piles are also placed against all vertical bearing piles along the dock side and along the Harbor Commissioners' line. These spur piles were driven on the required batter 1 foot in 3 feet; not driven straight and then pulled into position. All spur piles are carefully fitted against the bearing piles and secured to same with two 1¼-inch bolts. The heads of spur piles against the outer group piles are at elevation + 5; the heads of spur piles against all outer bearing piles are at elevation + 10.

The outer rows of bearing piles on the south and east sides of wharf are tenoned on top to receive the 12-inch by 12-inch cap stringer, the latter being properly mortised to receive same, tenons 4 inches by 6 inches by 6 inches, the cap stringers being dapped 2 inches on head of piles and secured to same by 1¼-inch oak treenails, all tenons being coated with white lead. The intermediate or outer stringers immediately above the cap stringers, and in the same plane as the floor stringers, are secured to each transverse cap with 1-inch by 20-inch drift bolts, the same having butt joints on the transverse caps. The top stringpiece or backing log, 12 inches by 12 inches, is secured to the intermediate stringers with 1-inch by 20-inch drift bolts spaced 4 feet center to center. The outer cap stringers and top stringpiece are scarf-jointed, as shown. All these outer 12-inch by 12-inch stringers are in lengths of at least 30 feet and laid to break joints. All scarf joints of 12-inch by 12-inch caps and stringers are 2 feet long, bolted with four ¾-inch bolts. All scarf joints were coated with white lead.

The top stringpiece on the east side of the wharf is secured to each floor stringer with one 1-inch by 20-inch drift bolt.

The top stringpiece, or backing log, on each outer side of the wharf has the inner edge chamfered to a width of 1½ inches.

Fender piles are placed on the east and south sides of the wharf, spaced about 5 feet center to center. Fender piles against bearing piles are secured to same with one 1¼-inch through bolt, also to intermediate stringers with one 1¼-inch through bolt. Fender piles between bearing plates are secured to cap stringers and intermediate stringers with 1¼-inch bolts. About every 40 feet special long, large butt piles are used as fender piles, the tops extending above the wharf level about 5 feet, to serve as mooring posts. These special piles are secured to the main transverse cap timbers with 4-inch by ½-inch strap irons, in addition to the regular

bolted connections for all fender piles. All bolts securing fender piles in place have heads let into piles to a depth of 4 inches.

Between the tops of the fender piles and outside the backing log are placed 8-inch by 12-inch separating or fender pieces, fitted squarely and closely against the heads of the fender pile by squaring the latter sufficiently to receive same, and secured to the backing log with four $\frac{7}{8}$-inch by 14-inch drift bolts. The tops of these separating pieces are beveled 2 inches in their width. The tops of the fender piles are beveled to same plane as the separating pieces for a distance of 8 inches out and then neatly rounded off, as shown.

The specially constructed rounded corner of the wharf can probably be better understood from an examination of the detailed plans for same than by any lengthy description. Special long, heavy piles are used for the groups in this corner construction, and tiers of heavy back bracing and blocking is used, bracing the corner construction back to a group of piles in the rear of same; these different tiers of bracing being at the following elevations: The lower one at elevation mean low water, the upper one just below the wharf floor, and the third midway between the first two named. In this corner construction the groups of piles and all timber framing are carefully fitted and thoroughly through bolted together, as shown. The face of this corner is finished with 6-inch oak vertical sheathing, extending from the top of the wharf to elevation — 2, the sheathing being secured to the timber construction by $\frac{5}{8}$-inch drift bolts. Three 4-inch by $\frac{1}{2}$-inch iron straps extend around this corner, being secured to some by countersunk head bolts, one strap about 2 feet below the wharf floor, one at mean low water, and a third midway between the other two.

The wharf floor was constructed as follows:

Floor stringers are 6 inches by 12 inches, except under tracks on the north and south sides of pocket, where they are 10 inches by 12 inches. Stringers are placed generally about 2 feet center to center. Each stringer extends over at least two bays and generally over three bays, the butt joints coming on the center of transverse caps, stringers breaking joints throughout.

At every bearing the floor stringers are secured with one $\frac{5}{8}$-inch by 18-inch drift bolt. Floor stringers embracing pocket posts are secured to the latter with $\frac{7}{8}$-inch by 12-inch lag screws. The upper surfaces of all stringers are brought to a true plane that floor plank may have a full and even bearing over all of same. The floor planking is 3-inch yellow pine, sized to even thickness and secured to stringers with two 7-inch wire nails at each bearing, no plank being less than 8 inches wide, all being laid with $\frac{3}{8}$-inch open

joints. The floor planks were not permanently laid until the pocket posts were in position, when the planking was spiked in place, being neatly fitted around the pocket posts.

The exposed surfaces of backing log, separating timbers between fender piles, tops of fender piles and mooring piles, received two heavy coats of approved paint.

Among the principal quantities used for this work are 1100 oak piles, 200,000 feet board measure of yellow pine and 30,000 feet board measure of oak.

The contractors for this work were Messrs. Holbrook, Cabot & Rollins, of Boston, to whom, and to Mr. Fred Logan their foreman in charge, much credit is due for the faithful manner in which they carried out the intent of the specifications.

Fig. 1 shows the location of coal pocket at Lincoln Wharf.

Fig. 2 shows the general plan of foundation for coal pocket.

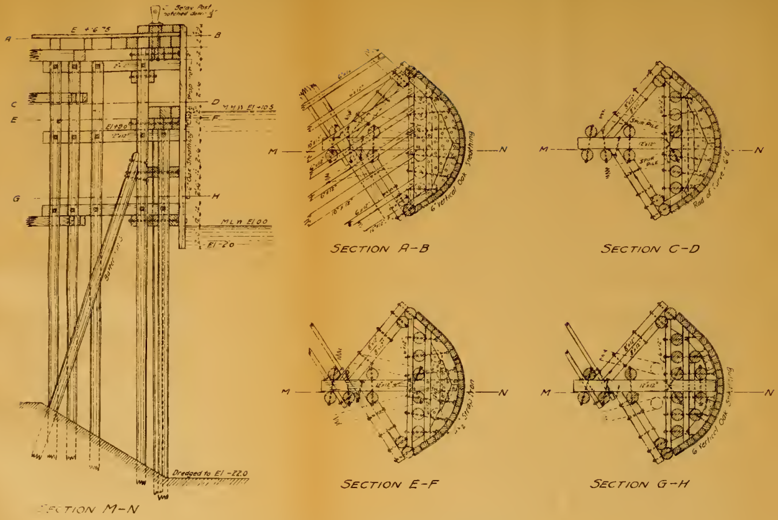
Fig. 3 shows the elevation of a typical bent in the foundation and general dimensions and arrangement of timbers in same.

Fig. 4 shows a plan of the bents and floor framing and general features of the design and construction.

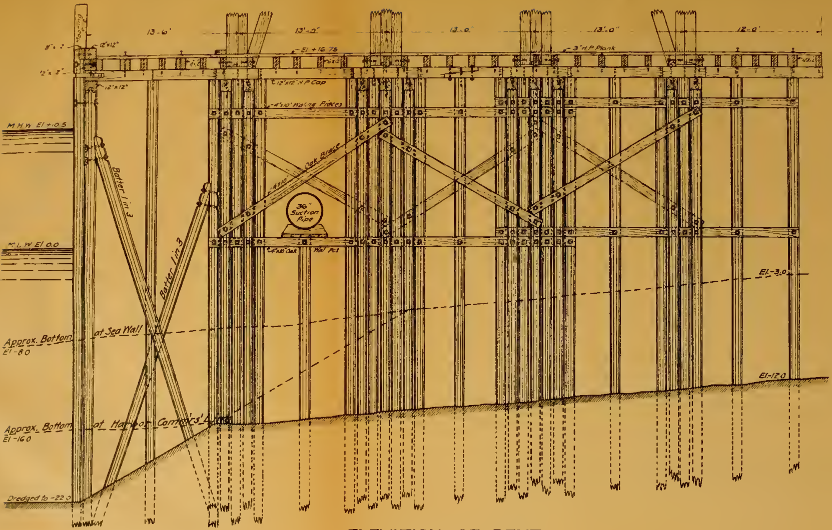
Fig. 5 shows the details of construction of the rounded corner at east end of the foundation.

Fig. 6 shows completed footing for pocket posts.

Fig. 7 shows the completed coal pocket.



DETAIL OF CORNER FRAMING



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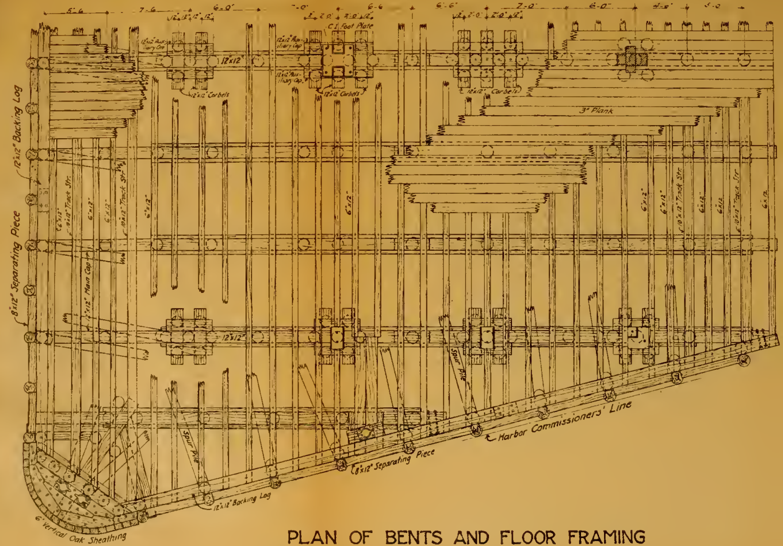

PLAN OF BENTS AND FLOOR FRAMING

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ESTIMATING SOIL STRIPPING FROM WATER-SUPPLY RESERVOIRS.

[Papers and discussion at the meeting of the Boston Society of Civil Engineers held January 14, 1903.]

A COMPARISON OF THREE METHODS OF ESTIMATING QUANTITIES OF SOIL STRIPPING FROM WATER-SUPPLY RESERVOIRS.

BY FRANK S. HART, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

THE Sudbury Reservoir, the largest artificial water-supply reservoir at present completed in New England, contains over 7,250,000,000 United States gallons of water, and covers, at high water, 1290 acres of surface.

This reservoir was planned and its construction commenced in 1895 by the Boston Water Works to develop, to the greatest practicable extent, the capacity for water supply of the northern portion of the Sudbury River water shed.

This reservoir and all of the other reservoirs and water-supply property of the Boston Water Works in this region have since been turned over to their successors, the present Metropolitan Water Works.

In accordance with the practice which has prevailed on the Boston Water Works since the year 1883, and which is accepted by the Metropolitan Water Works as being a prime requisite for the treatment of storage basins, nearly the whole of this area required the removal of the thin layer of loam or earth in which there was a relatively large proportion of organic matter.

Ordinarily this layer was about a foot thick, sometimes much thinner; but, here and there, pockets and swamps or meadows were found in which the deposits were of considerable depth.

In some cases it was deemed inadvisable to excavate the full depth of mud, because the lower layers contained only a small proportion of organic matter or because these places would be at all times covered with water to such depth as to prevent the deterioration of the water stored to any serious extent.

Some other deep deposits of questionable material were covered with a layer of sand or gravel so as to nullify, in a great degree, their influence.

The removal of this material was classed as soil stripping. It came to be the fashion later to call the material itself soil stripping.

There were over 4,000,000 cubic yards of this work involved in the construction of the reservoir, costing over $1,000,000, and divided among 9 contractors in 17 contracts, and ranging in price from 19 to 36 cents per cubic yard.

I understand that some of this excavation was sublet as low as 16 cents per cubic yard.

The contractors resorted to various methods for excavating, transporting and placing this material outside the limits of the completed reservoir.

Picks and shovels, mattocks and axes, knives and scoops drawn by horses all had their turn and try on sod, roots, muck and loam, as the previous experience or inexperience of the individual contractors persuaded them to consider advisable; and one contractor finally resorted to a hydraulic dredging plant.

I was informed that this plant, after it was adjusted to the conditions and managed skillfully, did the work for less than $\frac{1}{3}$ of the contract price per cubic yard, and in the end brought to the contractor a good profit, despite losses and adverse circumstances at the beginning.

The transporting was done by wheelbarrows, horse and mule teams, narrow-gauge railroad dump cars hauled by horses, or light steam locomotives, or by inclined railways with stationary engines, according to the multitude of conditions regarding location, kind of material, length of haul and the ideas and financial abilities of the several contractors and the different apparatus and plant already on hand.

The hydraulic plant used water carriage through a longer or shorter stretch of pipe as required.

Fourteen of the contracts included 2 working seasons, from about the first of May to the first of December of the next year.

The time of 7 of them included the winter of 1895-6, and 9 of them the winter of 1896-7.

The breaking of the job into 2 seasons when the depth excavated was barely 1 foot would necessarily require thorough and satisfactory work the first time any area was gone over, or

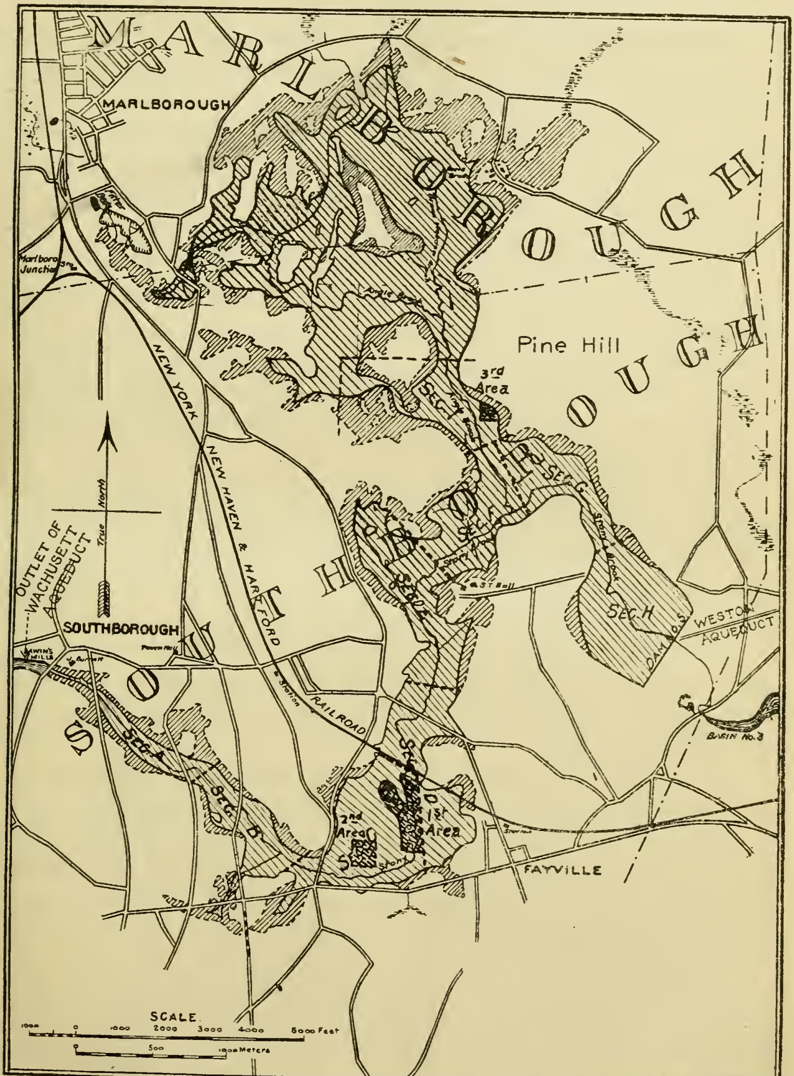


Plate A. General Plan of Sudbury Reservoir, Indicating the Location of the Several Areas of Investigation.

the cleaning up involved in slovenly, half-finished stripping would make the cost per cubic yard much in excess of the price bid.

Naturally, under the above circumstances, the question as to which was the proper way for the engineers to measure the amounts

of soil stripping for the monthly and final estimates came out prominently, and when these estimates fell short of the sometimes sanguine expectations of some contractor the word of dissatisfaction or criticism was heard more or less emphatically.

The subject had, of course, received sufficient and decisive consideration before such times by the Resident Engineer and General Superintendent of the Western Division of the Boston Water Works, your Past President, Mr. Desmond FitzGerald, under whose general direction the work had been laid out and started, and who has since continued and completed it as Engineer of the Sudbury Department of the Metropolitan Water Works.

However, feeling that as the complaints and criticisms might possibly become chronic and epidemic and likely to be legally troublesome, Mr. FitzGerald concluded that, as there offered a good opportunity, he would make an exhaustive and practical comparison of 3 of the most prominent and popular methods brought to his attention, and also test another method suggested by a complaining contractor.

The writer was selected to make a careful investigation into the whole subject, and at Mr. FitzGerald's kind suggestion and permission will embody the results of his work briefly in the few following pages which he hopes his fellow engineers will find both interesting and instructive in some slight degree.

The regular method of measuring the volumes of earth excavation, popularly called soil stripping, was adopted as the first method and is so referred to in this paper, and is also called the 50-foot-strip method.

It had been in use for some years in calculating the work on other reservoirs and had hitherto been considered satisfactory.

By this method the areas to be considered were divided carefully by instrument and tape into squares of 500 feet on a side, and, before the sections were entered upon by the contractor, profiles of the original surfaces were taken on lines 50 feet apart and parallel to one of the sides of these squares.

The leveling was done carefully, convenient benches being first accurately established, the "heights of instrument" taken to the nearest hundredth of a foot elevation and the work checked back to the bench started from or to some other equally well-determined bench.

The readings for the ground surfaces were taken to the nearest tenth of a foot. These notes were plotted on roll profile paper and carefully checked. The scales used were 3 feet to the inch vertical and 40 feet to the inch horizontal, Queen's continuous profile paper, plate B, being found well adapted for the purpose. The

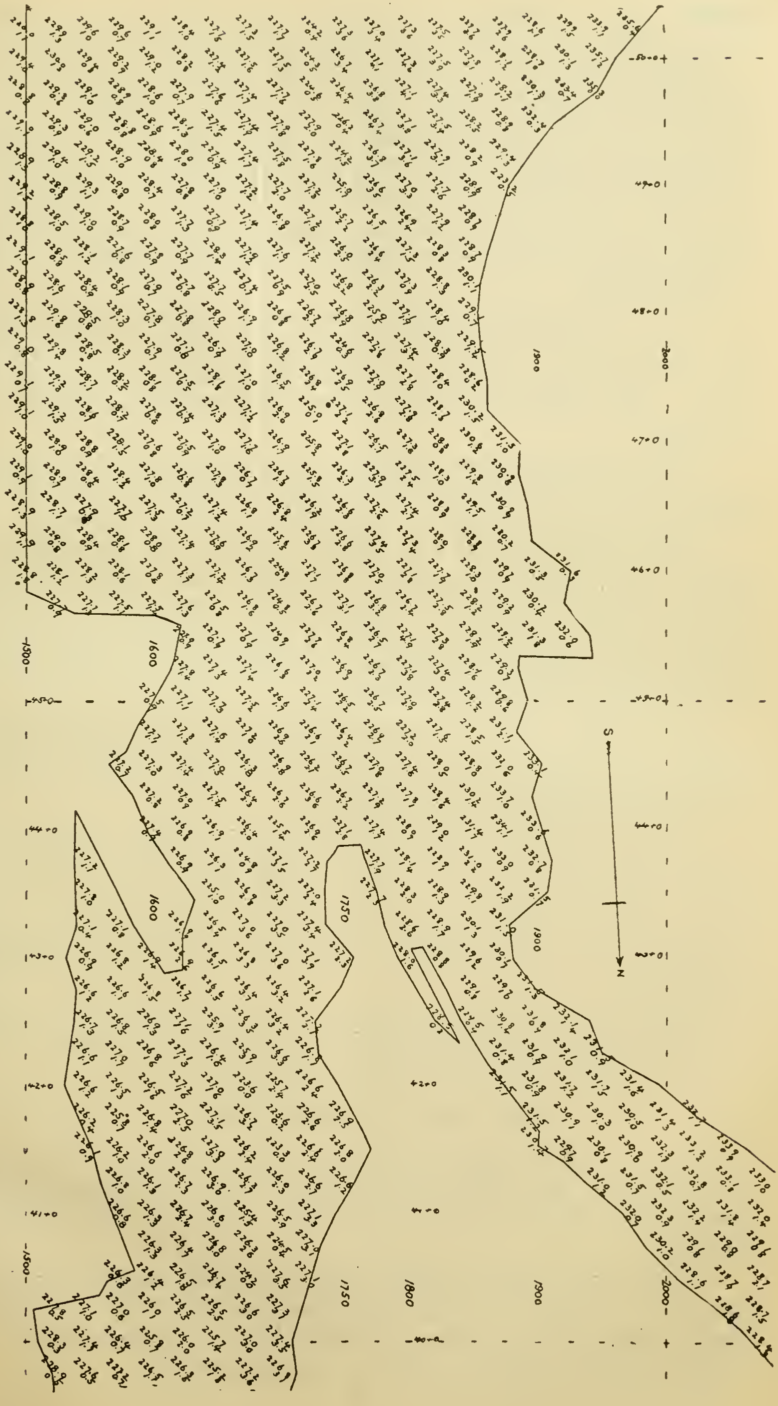


Plate B. Plan Showing Part of the First Area of Investigation, with Elevations of the Original Surface and Depths of Soil Stripping at the Corners of the 25-foot Squares.

profiles were so arranged as to allow room for subsequent ones on these same section-lines when changed by the removal of the soil.

These profiles were repeated monthly whenever the contractor had done any work on these lines, or as often as necessary to include all of his work of excavation up to the date for the estimate pending, and when the contractor had satisfactorily completed any sufficiently extensive area the profiles of that part were taken with particular care to use in making the final estimate, so as to closely include between them and the original profiles the amount of work to be reported.

The vertical areas included between the original surface profile and the profile showing the state of the work at the last survey were obtained by a planimeter measurement checked by a second person. This method is found to give a very satisfactory degree of accuracy.

These "section areas" were used as "end areas" 50 feet apart in the ordinary way of computing earth work, care being taken to fulfill geometrical conditions at the outskirts of the excavation.

The second method was exactly the same as the first and regular one, only the profiles and sections were taken 25 feet apart, or twice as often. In making the comparison with the regular method on the pieces of soil stripping selected, the regular 50-foot lines, profiles and sections were used, and the others were taken exactly one-half way between.

This second method is also referred to as the 25-foot strip method, and, because of its being the one requiring the greatest number of elevations to be determined, it was chosen as the standard method to compare the others with.

The third method abandoned the idea of profiles, plotting and sections, and took elevations only at the corners of 25-foot squares on the original surface and on the finished excavation, and the mean of these 4 differences of elevation or depths of cutting was considered as the mean depth of excavation for the square of 625 square feet.

Irregular boundaries and broken squares were, of course, carefully considered and allowed for in the several estimates.

Three areas were selected for comparison.

FIRST AREA OF INVESTIGATION.

The first and largest area was located in Section C, along Stoney Brook, next south of where the New York, New Haven and Hartford Railroad crosses the basin, just above the Fayville Station.

This area contained nearly 14½ acres, being about 1800 feet long and of irregular width, averaging about 350 feet. It was a narrow piece of the meadow on both sides of the brook, with a border of gently sloping upland on the westerly side.

PLATE C. TYPICAL PROFILES FROM THE FIRST AREA OF INVESTIGATION.

The mud or muck in the meadow was at places 3 or 4 feet deep, usually covered with a heavy, tough sod, and the loam on the upland hillside was about a foot deep, more or less interspersed with boulders and stumps of trees.

In order to show what larger differences, by comparison, may be balanced in a general average when the volume of stripping from a large area (over 14 acres in this case) is considered by the various methods, a subdivision into four parts has been made of the total area, and one of the best proportioned and defined of these parts has been further considered in 10 strips of 50 feet width each.

While these comparisons were in progress the regular work of the engineers was being carried on and involved a monthly estimate of the amount moved from this section.

As all but a very small portion of the material from this area was moved by dump cars on a narrow-gauge railroad, the opportunity was taken advantage of to compare car loads with our other measurements; these comparisons will be referred to later.

The following tables, I and II, have been prepared, showing the amounts of excavation for the different parts by the several methods of estimating, considering, as previously stated, the estimates by the strips 25 feet wide as standards, and rating them as unity in the comparisons with the estimates by the other methods.

TABLE I.

Estimates of the Amount of Excavated Materials Moved by Cars from the "First Area of Investigation."

Location of Area. Section C.		By Method of 25-foot Strips.		By Method of 50-foot Strips.		By Method of 25-foot Squares.	
Between Stations.	Included in	Cu. Yds.	Stand'rd.	Cu. Yds.	Ratio to Stand'rd.	Cu. Yds.	Ratio to Stand'rd.
35 + 25 and 40 + 0	July estimate	3642.7	*1.0000*	3485.2	*0.9568*		
35 + 25 and 40 + 0	Aug. estimate	2624.2	*1.0000*	2654.9	*1.0117*		
Area=2.68 acres.		6266.9	*1.0000*	6140.1	*0.9798*	6200.0	*0.9893*
40 + 0 and 45 + 0	July estimate	3672.2	*1.0000*	3788.4	*1.0316*		
40 + 0 and 45 + 0	Aug. estimate	6237.2	*1.0000*	6193.2	*0.9929*		
Area=3.88 acres.		9909.4	*1.0000*	9981.6	*1.0073*	9938.5	*1.0029*
45 + 0 and 50 + 0	July estimate	4347.4	*1.0000*	4313.0	*0.9921*		
45 + 0 and 50 + 0	Aug. estimate	5923.0	*1.0000*	6066.5	*1.0242*		
Area=4.32 acres.		10270.4	*1.0000*	10379.5	*1.0106*	10350.3	*1.0078*
50 + 0 and 55 + 25	July estimate	2870.1	*1.0000*	2871.6	*1.0005*		
50 + 0 and 55 + 25	Aug. estimate	4774.5	*1.0000*	4711.0	*0.9867*		
Area=3.53 acres.		7644.6	*1.0000*	7582.6	*0.9919*	7585.0	*0.9922*
Totals..................	July estimate	14532.4	*1.0000*	14458.2	*0.9949*		
	Aug. estimate	19559.0	*1.0000*	19625.6	*1.0034*		
Area=14.41 acres...		34091.4	*1.0000*	34083.8	*0.9998*	34073.8	*0.9995*

TABLE II.

ESTIMATE OF THE AMOUNT OF EXCAVATED MATERIALS MOVED BY CARS FROM A SELECTED SECTION OF THE "FIRST AREA OF INVESTIGATION."

LOCATION OF AREAS.	July Estimate, Cubic Feet.	August Estimate, Cubic Feet.	Total Cubic Feet.	Amount by 25-Foot Squares.	
				Cubic Feet.	Ratio to Standard.
Strip 25 feet wide 45 + 0 to 45 + 25	6499.9	6085.5	12585.4	12907.3	*1.0256*
Strip 25 feet wide 45 + 25 to 45 + 50	7134.8	6206.1	13340.9	13936.8	*1.0447*
Sum of above strips (standards)	13634.7	12291.6	25926.3	26844.1	*1.0354*
Same by strip 50 feet wide	13490.9	13951.7	27442.6		
Ratio of 50-foot strip to standard	*0.9895*	*1.1351*	*1.0585*		
Strip 25 feet wide 45 + 50 to 45 + 75	7264.9	7567.3	14832.2	14560.7	*0.9817*
Strip 25 feet wide 45 + 75 to 46 + 0	7028.5	9078.0	16106.5	15600.1	*0.9686*
Sum of above strips (standards)	14293.4	16645.3	30938.7	30160.8	*0.9749*
Same by strip 50 feet wide	14372.8	16515.7	30888.5		
Ratio of 50-foot strip to standard	*1.0056*	*0.9922*	*0.9984*		
Strip 25 feet wide 46 + 0 to 46 + 25	6614.1	7947.5	14561.6	14821.9	*1.0179*
Strip 25 feet wide 46 + 25 to 46 + 50	5987.3	7642.0	13629.3	14304.1	*1.0495*
Sum of above strips (standards)	12601.4	15589.5	28190.9	29126.0	*1.0332*
Same by strip 50 feet wide	12968.8	16185.5	29154.3		
Ratio of 50-foot strip to standard	*1.0292*	*1.0382*	*1.0342*		
Strip 25 feet wide 46 + 50 to 46 + 75	5745.5	7522.5	13268.0	13522.2	*1.0192*
Strip 25 feet wide 46 + 75 to 47 + 0	5801.3	7248.9	13050.2	12855.7	*0.9851*
Sum of above strips (standards)	11546.8	14771.4	26318.2	26377.9	*1.0023*
Same by strip 50 feet wide	11300.4	15677.4	26977.4		
Ratio of 50-foot strip to standard	*0.9787*	*1.0613*	*1.0250*		
Strip 25 feet wide 47 + 0 to 47 + 25	5525.0	7203.8	12728.8	12473.9	*0.9800*
Strip 25 feet wide 47 + 25 to 47 + 50	4946.0	6938.1	11884.1	12481.3	*1.0503*
Sum of above strips (standards)	10471.0	14141.9	24612.9	24955.2	*1.0139*
Same by strip 50 feet wide	10007.5	14788.9	24796.4		
Ratio of 50-foot strip to standard	*0 9557*	*1.0458*	*1.0075*		
Strip 25 feet wide 47 + 50 to 47 + 75	4422.6	7315.4	11738.0	12371.9	*1.0540*
Strip 25 feet wide 47 + 75 to 48 + 0	3384.1	8109.5	11493.6	11740.0	*1.0214*
Sum of above strips (standards)	7806.7	15424.9	23231.6	24111.9	*1.0379*
Same by strip 50 feet wide	7107.2	15610.3	22717.5		
Ratio of 50-foot strip to standard	*0.9104*	*1.0120*	*0.9779*		
Strip 25 feet wide 48 + 0 to 48 + 25	2058.6	8494.8	10553.4	11310.6	*1.0717*
Strip 25 feet wide 48 + 25 to 48 + 50	1878.0	8683.3	10561.3	11168.8	*1.0575*
Sum of above strips (standards)	3936.6	17178.1	21114.7	22479.4	*1.0646*
Same by strip 50 feet wide	4441.3	17823.4	22264.7		
Ratio of 50-foot strip to standard	*1.1282*	*1.0376*	*1.0545*		
Strip 25 feet wide 48 + 50 to 48 + 75	3115.8	8962.3	12078.1	12086.3	*1.0007*
Strip 25 feet wide 48 + 75 to 49 + 0	4906.1	8808.1	13714.2	13572.2	*0.9896*
Sum of above strips (standards)	8021.9	17770.4	25792.3	25658.5	*0.9948*
Same by strip 50 feet wide	8219.3	17333.8	25553.1		
Ratio of 50-foot strip to standard	*1.0246*	*0.9754*	*0.9907*		
Strip 25 feet wide 49 + 0 to 49 + 25	6266.1	8893.1	15159.2	15200.0	*1.0027*
Strip 25 feet wide 49 + 25 to 49 + 50	7668.6	8972.9	16641.5	16492.9	*0.9911*
Sum of above strips (standards)	13934.7	17866.0	31800.7	31692.9	*0.9966*
Same by strip 50 feet wide	13681.3	18108.8	31790.1		
Ratio of 50-foot strip to standard	*0.9818*	*1.0136*	*0.9997*		
Strip 25 feet wide 49 + 50 to 49 + 75	9578.5	9145.5	18724.0	17934.1	*0.9578*
Strip 25 feet wide 49 + 75 to 50 + 0	11554.8	9097.6	20652.4	20117.5	*0.9741*
Sum of above strips (standards)	21133.3	18243.1	39376.4	38051.6	*0.9664*
Same by strip 50 feet wide	20861.3	17800.0	38661.3		
Ratio of 50-foot strip to standard	*0.9871*	*0.9757*	*0.9818*		
TOTAL—25-foot strips 45 + 0 to 50 + 0	117380.5	159922.2	277302.7	279458.3	*1.0078*
50-foot strips 45 + 0 to 50 + 0	116450.8	163795.1	280245.9		
RATIO	*0.9921*	*1.0242*	*1.0106*		

Of the results shown in Table I, the following may be referred to here as of especial interest: The lowest ratio by the 50-foot strip method is 95.68 per cent., with a volume of about 3650 cubic yards, and the highest ratio is 103.16 per cent., with a volume of about 3675 cubic yards, while for the total amount of nearly 34,100 cubic yards on this area of about 14½ acres the ratio is 99.98 per cent.

By the 25-foot square method the lowest ratio is 98.93 per cent. (as against 97.98 per cent. by the 50-foot strip method) for a volume of about 6270 cubic yards, and the highest ratio is 100.78 per cent. (as against 101.06 per cent. by the 50-foot strip method) for a volume of about 10,270 cubic yards, while for the total amount of nearly 34,100 cubic yards, as above, the ratio is 99.95 per cent., the 5 parts compared being in each case nearer the standard by the 25-foot square method, while the totals agree almost exactly with each other, as well as with the standard.

A corresponding analysis of Table II shows that, in that part of the area which was still further subdivided (4.3 acres), the lowest ratio by the 50-foot strip method is 91.04 per cent. for a volume of over 7800 cubic feet, and the highest ratio is 113.51 per cent. for a volume of less than 12,300 cubic feet, while by the 25-foot square method the lowest ratio is 95.78 per cent. for a volume of over 18,700 cubic feet, and the highest ratio is 107.17 per cent. for a volume of over 10,550 cubic feet.

The totals compare 101.06 and 100.78 per cent. for the 50-foot strips and the 25-foot squares, respectively, as is also shown for this portion in Table I.

In the above instances the 25-foot squares show closer ratios to unity than do the 50-foot strips, but in the comparisons that can be made, 6 cases out of the 10 show the estimates for the 50-foot strips to be closer to the standards than are the corresponding estimates by the 25-foot squares.

CAR MEASUREMENTS.

The opportunity before referred to of comparing "car measurement" with measurement in excavation was availed of under fairly good circumstances.

It was particularly understood that the contractor was to be entirely uninfluenced, either by any direction of the work on the

part of the engineers or through any information from them of the count to be made and inspection to be maintained.

Directions were necessarily given from time to time relative to the kind of material to be or not to be removed, the same as if no count and accompanying inspection were to be made; otherwise the above understanding was faithfully carried out.

The contractor was aware, of course, from the constant presence of the observer and his use of the note-book and the careful measurement of the essential dimensions of his cars by the engineers which was impossible to avoid or conceal that something of

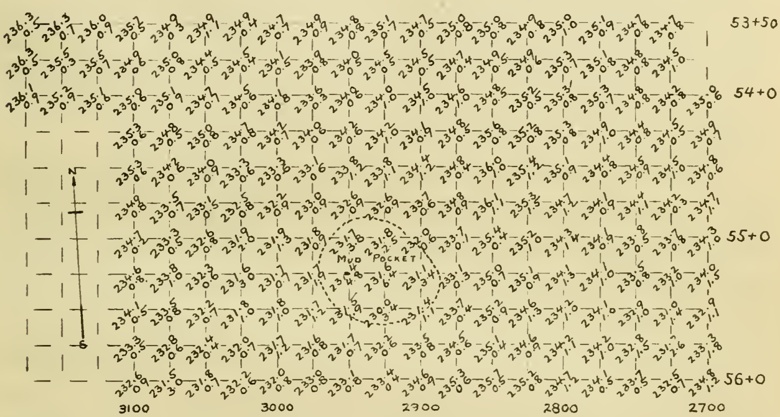


PLATE D. PLAN SHOWING PART OF THE SECOND AREA OF INVESTIGATION WITH ELEVATIONS OF THE ORIGINAL SURFACE AND DEPTHS OF SOIL STRIPPING AT THE CORNERS OF THE 25-FOOT SQUARES. THIS INCLUDES THE LOCATION OF THE DEEP "MUD POCKET" REFERRED TO IN THE TEXT.

the sort was going on; but, other than the apparent variation in the fulness of the loading of cars, it seemed to make no difference in his control or direction of the work or in his choice of methods.

There were 46 dirt cars of the one-side dump pattern on the premises, all but one of which were in very fair condition and in use during some part of the time of the count.

At first only 2 trains (10 cars loading and 10 cars dumping) were in use on our area. Afterward, from June 23d onward, another similar pair was put on.

There were usually 10 cars in a train, with 2 shovelers to a car, but the number of cars was varied as occasion demanded, sometimes there being as many as 15 or 16 and at other times as few as 5 or 6 cars.

Cars were damaged from time to time and others of the 46 were put in their places, the broken ones meanwhile being repaired and put in readiness in case of other breaks.

Each of the cars was numbered plainly, the numbers running from 21 to 66, inclusive.

Each car was carefully measured to obtain its "struck capacity" and a record kept.

The capacities found were quite uniform, averaging 76.27 cubic feet per car, the smallest being 74.91 and the largest 77.88 cubic feet.

The general dimensions of the cars were as follows: $2\frac{1}{3}$ feet deep below the striking line; $5\frac{3}{4}$ feet wide from side to side, and 6 feet long at the door side and $5\frac{1}{2}$ feet long at the opposite side.

The average area at the top of the cars, the struck level on which material could be heaped, was about 33 square feet.

When all previous work of excavation on or bordering on this area of investigation had been carefully located and measured, a competent person was stationed on the premises to keep count of all of the cars that took any material away and make record of the times of setting and pulling out of the trains, the time occupied in filling the cars, the number of cars in each train and their numbers, the number of shovelers at work, the comparative fulness of the cars when taken away and the kind of material excavated, whether mud or loam.

Four designations for the comparative fulness of the cars were used, viz: A, for heaping up full; B, for well-rounded loads, but with slack (that is partly empty) corners; C, for what would be judged to be even full if leveled off, and D, for a rather slack load. There were also several cases when some of the cars were only about $\frac{1}{2}$ or $\frac{1}{4}$ full at the time the train was started for the dump. A was estimated to represent 3.640 cubic yards gross measurement; B was estimated to represent 3.232 cubic yards gross measurement; C was estimated to represent 2.825 cubic yards gross measurement, and D was estimated to represent 2.640 cubic yards gross measurement.

The records show that the cars were better filled during the first part of the count than they were later on.

The following table, No. III, of the number of cars and gross quantities moved, will give some idea of how the loading varied:

TABLE III.

STATEMENT OF THE ITEMS OF THE CAR-COUNT MADE ON SECTION "C" OF THE AMOUNT OF MATERIALS MOVED FROM "FIRST AREA OF INVESTIGATION."

1896. DATES, ETC.	Number of Car Loads and Condition of Loading.						Totals.		Average Number of Cubic Yards per Car.
	A. (Heaping full.)	B. (Well rounded.)	C. (Even full.)	D. (Slack.)	½ Full.	¼ Full.	Number of Car Loads Carried.	Gross Amount Carried Cubic Yards.	
From June 11th to July 3d, 29 days' work of two gangs	103	2261	1089	193	4	0	3650	11274.0	3.089
From July 4th to July 15th, 17 days' work of two gangs..	5	1297	825	119	14	0	2260	6874.7	3.042
Sum of above for July estimate	108	3558	1914	312	18	0	5910	18148.7	3.071
From July 16th to July 28th, 20 days' work of two gangs..	15	1193	945	242	8	0	2403	7230.2	3.009
From July 29th to Aug. 8th, 20 days' work of two gangs..	0	875	1520	256	20	0	2671	7826.1	2.930
From Aug. 10th to Aug. 21st, 19 days' work of two gangs..	0	653	1486	267	61	6	2473	7103.7	2.873
Sum of 3 next above for Aug. est.	15	2721	3951	765	89	6	7547	22160.0	2.936
Total for July and Aug. ests.....	123	6279	5865	1077	107	6	13457	40308.7	2.995

August estimate, including 404.9 cubic yards moved by carts, 22564.9
Total " " 404.9 " " " " " 40713.6

For the several days previous to the beginning of the count, when the idea of car measurements was prominently in the minds of the contractor and his engineer and foremen, and advocated by them as the proper way to estimate the amounts of soil stripping, the proportionate number of well-filled cars was noticeably greater even than that shown in the table as between June 11th and July 3d, which gives nearly 3 per cent., or between June 11th and June 22d (not shown in the table), which last-mentioned period furnish records giving over 7 per cent. greater fulness than the average for the whole time.

Owing to the sticky condition of the material excavated, most of the cars returned from the dump with considerable dirt, mud or muck still adhering to the sides and bottoms. It was estimated that the average amount per car was about 5 cubic feet. No allowance was made for this lessened capacity in reckoning the gross amounts by car measurement.

Near the conclusion of the work the contractor found it advisable to move some of the material by horses and carts. Some of this was reloaded into the cars and the rest carried in the carts

off to another dump. Of this latter, 458 1-horse loads and 62 2-horse loads were counted, the carts measured and the gross amount was estimated to be 404.09 cubic yards and considered as subject to the same proportion of swelling and shrinkage as the materials moved by the cars. This made the total gross amounts by car and cart measurement for the July estimate 18,148.7 cubic yards, and for the August estimate 22,564.9 cubic yards, or a total of 40,713.6 cubic yards.

The amounts shown in Table I by the standard or 25-foot strip method are, for the July estimate, 14,532.4 cubic yards, and for the August estimate, 19,559 cubic yards, or a total of 34,091.4 cubic yards. Of the July portion of this latter amount there was estimated to be about 50 cubic yards of stone and stumps left on the area and not removed by the cars, and of the August portion about 180 cubic yards were likewise stones and stumps not included in the car measurements.

The standard estimates should, therefore, be decreased accordingly before comparison is made with the amounts by car measurements.

We have, then, by standard measurements, 14,482.4 cubic yards in July, 19,379 cubic yards in August, or a total of 33,861.4 cubic yards to compare with car measurements of 18,148.7 cubic yards, 22,564.9 cubic yards and 40,713.6 cubic yards, respectively, and find the ratios to be as follows:

For the July estimate	1 to 1.253 or 1 to $\frac{1}{0.7980}$
" " August estimate	1 to 1.164 or 1 to $\frac{1}{0.8588}$
And for the total estimate	1 to 1.202 or 1 to $\frac{1}{0.8317}$

The reciprocals are given to show reverse comparison.

It may be interesting to note here the agreement of the above results with the statement contained in the following quotation from Trautwine's *Engineers' Pocket Book*, page 741 of the 15th edition, 1891, on "Shrinkage of Embankments": "Although earth, when first dug and loosely thrown out, *swells* about $\frac{1}{5}$ part, so that a cubic yard in *place* averages about $1\frac{1}{5}$ or 1.2 cubic yards when dug, or 1 cubic yard dug is equal to $\frac{5}{6}$ or 0.8333 of a cubic yard in place, yet when made into embankments it gradually subsides, settles or shrinks into a less bulk than it occupied before being dug."

SECOND AREA OF INVESTIGATION.

The second piece selected for investigation was also in Section C, southwesterly from the first piece and located between section lines 51 + 0 and 56 + 0 north and south and ranges 2700 and 3200 east and west.

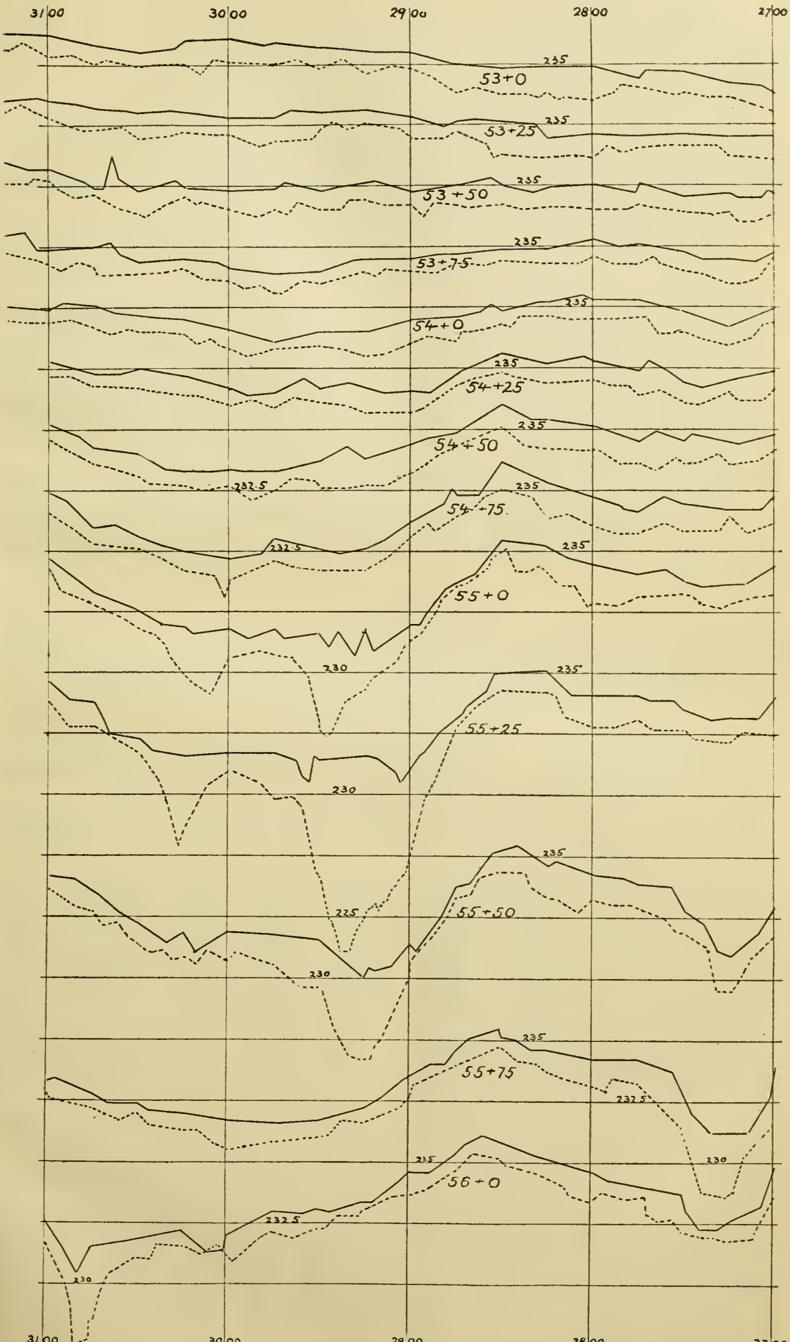


PLATE E. PROFILES FROM THE SECOND AREA OF INVESTIGATION, INCLUDING THE LOCATION OF THE DEEP "MUD POCKET."

It did not occupy the whole of the rectangle indicated by these lines, but was so bounded as to have full squares and to be entirely inside an area previously untouched by the contractor.

It contained about $4\frac{3}{4}$ acres of not very smooth upland pasture, with a small bog hole or mud pocket as a special feature. As on the first area, profiles were taken of lines 25 feet apart and elevations were taken at the corners of 25-foot squares.

The depression at the mud pocket was the only condition likely to occasion any great difference in the estimates by different methods. Its effect will be made apparent in the detailed comparison. It was intersected by sections 55 + 0, 55 + 25 and 55 + 50, and by lines 2900, 2925 and 2950, with a maximum depth of cutting as indicated by the 25-foot squares of 6.4 feet, the average being 3.74 feet. The maximum cut by a 50-foot section was 3.9 feet, while by a 25-foot section it was 7.9 feet.

The following table, IV, shows the results by the three methods of estimating, giving the details and proportions for the 50-foot strips:

TABLE IV.

ESTIMATES OF THE AMOUNT OF EXCAVATED MATERIALS TAKEN FROM THE PART OF SECTION C, CHOSEN AS THE "SECOND AREA OF INVESTIGATION."

UPLAND—AREA, 4.71 ACRES.

Location of Area. Section C.		By Method of 25-foot Strips.		By Method of 50-foot Strips.		By Method of 25-foot Squares.	
By Section.	By Lines.	Cu. Yds.	Stand'rd.	Cu. Yds.	Ratio to Stand'rd.	Cu. Yds.	Ratio to Stand'rd.
51 + 0 to 51 + 50	2750 to 3125	700.0	*1.0000*	699.0	*0.9986*	701.4	*1.0020*
51 + 50 to 52 + 0	2750 to 3125	706.4	*1.0000*	723.7	*1.0245*	689.8	*0.9765*
52 + 0 to 52 + 50	2725 to 3150	793.3	*1.0000*	763.2	*0.9621*	792.8	*0.9994*
52 + 50 to 53 + 0	2725 to 3150	707.4	*1.0000*	696.1	*0.9840*	728.0	*1.0291*
53 + 0 to 53 + 50	2725 to 3175	668.4	*1.0000*	679.3	*1.0163*	660.9	*0.9888*
53 + 50 to 54 + 0	2725 to 3175	600.3	*1.0000*	643.7	*1.0723*	552.1	*0.9197*
54 + 0 to 54 + 50	2700 to 3100	585.0	*1.0000*	625.0	*1.0684*	563.7	*0.9636*
54 + 50 to 55 + 0	2700 to 3100	701.5	*1.0000*	751.4	*1.0711*	694.4	*0.9899*
55 + 0 to 55 + 50	2700 to 3100	1087.6	*1.0000*	856.0	*0.7871*	1098.4	*1.0099*
55 + 50 to 56 + 0	2700 to 3100	732.6	*1.0000*	768.2	*1 0486*	727.4	*10.9929*
51 + 0 to 56 + 0		7282.5	*1.0000*	7205.6	*0.9894*	7208.9	*0.9899*

Here we find, for special instances, the lowest ratio by the 50-foot strips to be 78.71 per cent. and the highest to be 107.23 per cent., while the same areas gave, by the 25-foot squares, 100.99 and 91.97 per cent., which was a kind of a change about. The lowest ratio by the 25-foot squares is, as it happens, 91.97

per cent., which was for the same area as was the highest per cent. by the 50-foot strips, and the highest ratio by the 25-foot squares is 102.91 per cent., as against 98.40 per cent. for the same area by the 50-foot strips—a considerable diversity.

But, on taking the whole area, we find that almost exactly 1 per cent. is the difference from the standards, and both the 50-foot strips and the 25-foot squares are alike to within 1-20 of 1 per cent.

THIRD AREA OF INVESTIGATION.

The third area selected was in Section I, on the Angle Brook part of the reservoir, on a flat hillside. It contained about 2 acres of rough pasture land. The contractor had entered upon the work before we were able to take the elevations for the corners of the 25-foot squares, but the division engineer had taken the levels for the 50-foot and 25-foot profiles previously—about the time that this investigation was first being considered.

The following table, V, shows results in detail, with comparisons for the 50-foot strips:

TABLE V.

ESTIMATES OF THE AMOUNT OF EXCAVATED MATERIALS TAKEN FROM THE PART OF SECTION I, CHOSEN AS THE "THIRD AREA OF INVESTIGATION."

UPLAND—1.82 ACRES.

Location of Area Section I.		By Method of 25-foot Strips.		By Method of 50-foot Strips.		Areas of the 50-Foot Strip.
By Sections.	By Lines.	Cu. Yds.	Standard	Cu. Yds.	Ratio to Standard.	Sq. Feet.
9+50 to 10+0	8020 to 8500	766.48	*1.0000*	762.84	*0.9953*	24000
10+0 to 10+50	8040 to 8430	667.21	*1.0000*	663.47	*0.9944*	19500
10+50 to 11+0	8070 to 8380	541.19	*1.0000*	532.63	*0.9842*	15500
11+0 to 11+50	8080 to 8300	360.07	*1.0000*	347.87	*0.9661*	11000
11+50 to 12+0	8090 to 8220	214.96	*1.0000*	225.29	*1.0481*	6500
12+0 to 12+50	8090 to 8150	105.36	*1.0000*	108.41	*1.0289*	3000
9+50 to 12+50		2655.27	*1.0000*	2640.51	*0.9944*	79500
						1.82 acres.

The range of variation is from 96.61 per cent. to 104.81 per cent., and these extremes are for two contiguous strips. If these were taken together their divergences from the standard would almost neutralize each other and give a ratio of 99⅗ per cent., which simply emphasizes the principle that the larger the areas involved the nearer the ratios are likely to be to unity.

A summary of the results obtained by applying the three above methods of estimating to the quantities on the three areas

appears to abundantly corroborate and fully justify the opinion and decision of the engineer in charge, Mr. Desmond FitzGerald, for this kind of work.

It would seem from this investigation that the 25-foot strips were fine enough divisions for standards, and that profiles closer together could not reasonably be demanded and would not give much more reliable results when sufficiently large areas are taken and a generally uniform depth of cutting is to be considered.

From a contractor's point of view, one method is as likely to be as favorable to him as either of the others. But, from the engineer's standpoint, the questions of expedition and expense have considerable weight when choosing the method, and are very proper subjects for discussion.

Unfortunately, this investigation was undertaken under such conditions that no definite conclusions respecting these points could be obtained, and, accordingly, no positive statements of personal opinions regarding them will be offered at this time.

METHOD OF ESTIMATING QUANTITIES OF SOIL EXCAVATION FROM WACHUSETT RESERVOIR.

By Charles A. Bowman, Division Engineer, Metropolitan Water Works.

The Wachusett Reservoir, which is now being constructed by the Metropolitan Water Works in the towns of Clinton, Boyleston, West Boyleston and Sterling, will have a capacity, when completed, of 63,068,000,000 gallons.

Its construction requires the removal of soil from more than 4200 acres. It is the intention to remove from the basin all surface material containing any considerable amount of organic matter. To assist the inspectors in determining the minimum depth at which this requirement can be fulfilled, laboratory tests of soil from different depths are continually being made a little in advance of the soil-stripping work. Under eleven different contracts, 4,835,579 cubic yards, or 70 per cent. of an estimated total of 6,900,000 cubic yards, have already been removed from 2831 acres. A greater part of this soil has been used for embankment at the North Dike, but smaller quantities have been used in construction of roads and the treatment of shallow flowage areas. The contract prices for soil excavation, including disposal in embankment, have ranged from 15 to 39 cents per cubic yard, averaging 30.5 cents per cubic yard. The average depth over the area stripped is 1.06 feet. The general depth is considerably less than a foot, but occasional kettle holes and areas of limited extent in the lower lands require stripping to much greater depths.

The maximum depth of the reservoir will be 119 feet, and both outline and surface are very irregular.

The flat lands along the river, which in some cases are very narrow, extend back in other places for half a mile, and are terminated by deep bluffs, often at a slope of 38°. These bluffs in some places form the margin of the reservoir, but in others only separate the deeper portion of the basin from comparatively shallow areas of considerable extent, broken by islands and kettle holes which are nearly as deep as the main basin.

Before making the real estate surveys which were necessary on the site of the reservoir, a system of triangulation was established, with some fifty stations along the margins and in the basin.

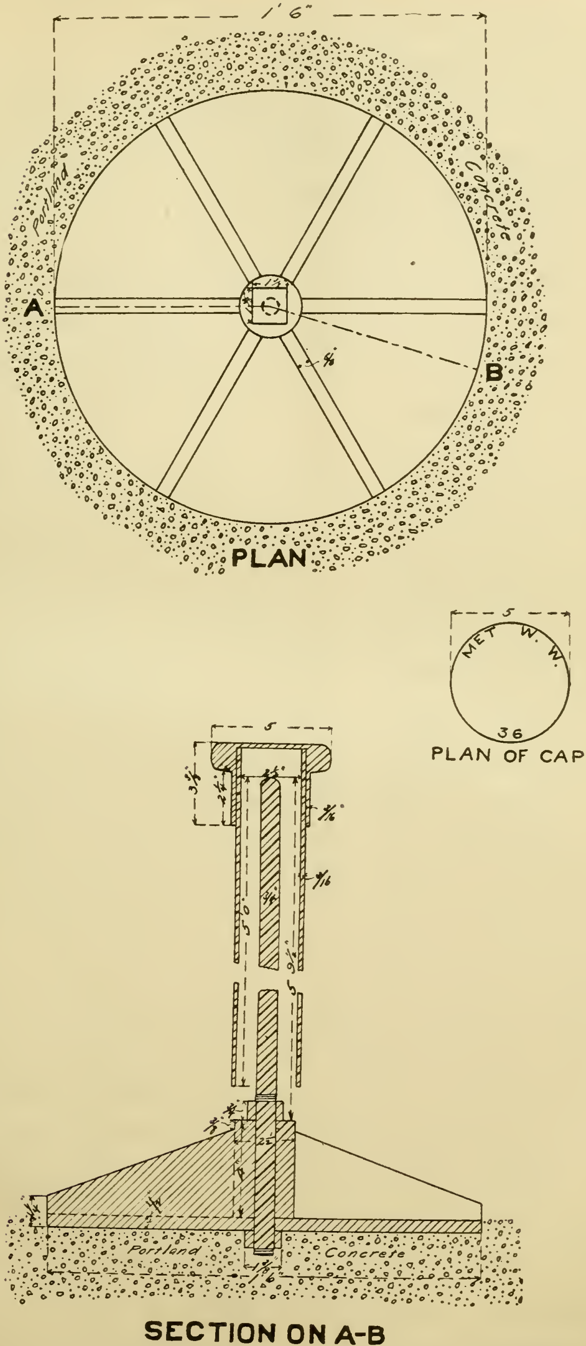
In connection with these stations, by triangulation from trial points set from the land survey traverses, points on opposite sides of the valley were established on co-ordinate lines both north and south and east and west at intervals of 1000 feet. From these points the intersecting lines were run out with a transit, and chest-

nut hubs (3 inches square and 3 feet long) were set at the corners of 1000-foot squares. By running out the diagonals of these squares and again intersecting from the centers thus established, similar chestnut hubs were set at each 500-foot corner.

Before setting these corners the soil was thrown out from a circle 3 or 4 feet in diameter, so as to drive the hub flush with the stripped surface. These hubs were centered with large wire nails and usually guarded by a triangular fence. Printed index sheets (see diagram) were prepared, showing the arrangement of 500-foot squares (1047 in number), and each hub was designated by the number of the square whose northwesterly corner it formed.

Thus the entire area to be stripped was cross-sectioned every 500 feet, without tape measurements other than those of a few feet to the 1000-foot co-ordinate lines from the trial points, the co-ordinate of which has been determined by triangulation. The topography of the country is such that this method was especially suited to it, and the errors of long tape measurements in an uneven area, much of which was not cleared, were avoided. Some fifty precise benches were set at convenient points near the flow line and within the basin. These benches consisted of an iron rod $\frac{3}{4}$ inch in diameter and 6 feet long, bolted to a cast-iron disk 18 inches in diameter. These disks were carefully set on concrete at such depths that the rods reach to near the surface, and the rods surrounded by a casing of $2\frac{1}{2}$-inch iron pipe, with a numbered cast-iron cover.

Very careful levels were run with a B. & B. precise level over these benches, the elevations adjusted and checked by cross runs. It was originally the intention to establish secondary benches on the wire nails in hubs at 500-foot corners for use in construction, and this method was used during the first year or two. There was often one and sometimes two or more winters between the taking of original and final levels, and, although the hubs were carefully set, these benches were never used a second year without carefully checking by level runs similar to those first made between precise benches. These test runs often showed unlooked-for changes of elevation in the hubs, and in order to avoid the necessity of careful readjustment it has been found advisable on the more recent work to set some hundred and fifty iron benches similar to the above-described precise benches, and fifty or more bolts where outcropping ledge furnished a suitable setting for the latter. Some old bridge iron was used for these intermediate benches, and they were not set on concrete, but carefully bedded in the natural material and thoroughly rammed. The elevations of these inter-



Commonwealth of Massachusetts, Metropolitan Water Works. Precise Level Bench Mark.

Scale, 1½ inches = 1 foot.

mediate benches are determined from level runs made with the ordinary B. B. 18-inch wye level.

At least four repetitions are required of the level runs between these benches before the elevations are adjusted, and if too great a variation from the average difference of elevation between any two points is found, additional runs are made before the adjustment of the chain of benches is completed. More than ordinary care is used in determining these bench elevations, because the average depth of excavation is so small that a slight error in bench elevation leads to a large per cent. of error in measurement of volume excavated. The method to be employed in the measurement of soil excavation is definitely stated in the specifications for each contract as follows:

"Soil excavation shall be measured in excavation and the amount of soil excavated shall be determined from levels taken when there is no frost in the ground, or if it shall become necessary to take levels when there is frost in the ground, the engineer shall make an allowance therefor. The first levels shall be taken before the contractor has commenced grubbing, and the final levels after he has completed the excavation of the soil. For convenience in estimating the quantity of soil excavated, the ground will be divided into squares 25 feet on a side, and the depth of excavation from each square will be determined by levels taken not more than 25 feet apart. In the case of partial squares, the estimates will be made as follows: If the area excavated is more than three-fourths of the area of the whole square, it will be estimated as a whole square; if from one-fourth to three-fourths of the area of the whole square, it will be estimated as if one-half of a square, and if less than one-fourth of the whole square, it will not be estimated."

Printed estimate sheets (see diagram) were prepared, each representing a 500-foot square, on a scale of 25 feet to an inch, divided into 25-foot squares. These 25-foot squares are designated by the letters A to T, running from left to right along the top of the sheet, and by numbers 1 to 20 from the top down on the left margin. O.s., f.s. and cut, printed in each of these small squares, indicate respectively the place for platting the elevation of original surface, final surface and the difference or cut. A column of spaces down the right margin of the sheet is used for the sum of cuts added horizontally across the sheet and in spaces across the bottom of the sheet are entered the sum of cuts in each vertical column of squares. At the lower right-hand corner is entered the total sum of cuts for the 500-foot square. This total

sum is conveniently checked by adding the sums of cuts in both the horizontal and vertical columns. The ruled spaces at the bottom of the sheet are for monthly and final estimates, areas of clearing and grubbing and signatures.

On the larger contracts the areas to be stripped have been divided into three or more classes. The usual division is into Classes A, B and C, Class A being level country with few trees or stumps, on which tracks can be readily thrown and the soil shoveled directly into cars; Class B including mostly rolling country which is all accessible to carts and sometimes to cars, and Class C comprising steep slopes, where it is necessary to cast the soil down or to build side-hill roads.

Different prices are paid for excavation from the different classes.

The division lines between these classes are made on even 100-foot lines, and where they cut a 500-foot square separate estimate sheets are used for each class.

The 500-foot squares are cross-sectioned every 25 feet with transit and tape. The stakes used for this purpose were sawed from lumber obtained in clearing the reservoir site, generally pine or spruce, $\frac{5}{8}$ x $\frac{5}{8}$ x 18 inches, planed on two sides so as to be readily marked.

A stake is set at the center of each 25-foot square.

Owing to the uneven nature of most of the area to be stripped, it is necessary to measure with considerable accuracy in setting these stakes, and especially important that each stake in the final work should occupy the same position as the corresponding one for the original sections.

It is customary to run out lines at intervals of 50 or 100 feet, setting the stakes with the transit, and then to fill in by stretching the tape between these lines. Sometimes the stakes are set by running out diagonal lines. The head of a cross-section party determines from inspection of the country the best method to be used in each square, and makes a record so that the squares may be laid out in the same way after the excavation is completed. On some of the more level areas two or more squares are cross-sectioned together, the skeleton lines are run at greater intervals and a 200-foot Roe tape is used for filling in. The measurements between 500-foot corners during this work usually check within one or two tenths.

The levels for o.s. and f.s. are started from one of the precise or intermediate benches already described and each run is checked onto another bench or back to the starting point.

The runs generally check within two hundredths or less, although three hundredths' error is sometimes allowed. Elevations are taken at each stake, reading to the nearest tenth of a foot.

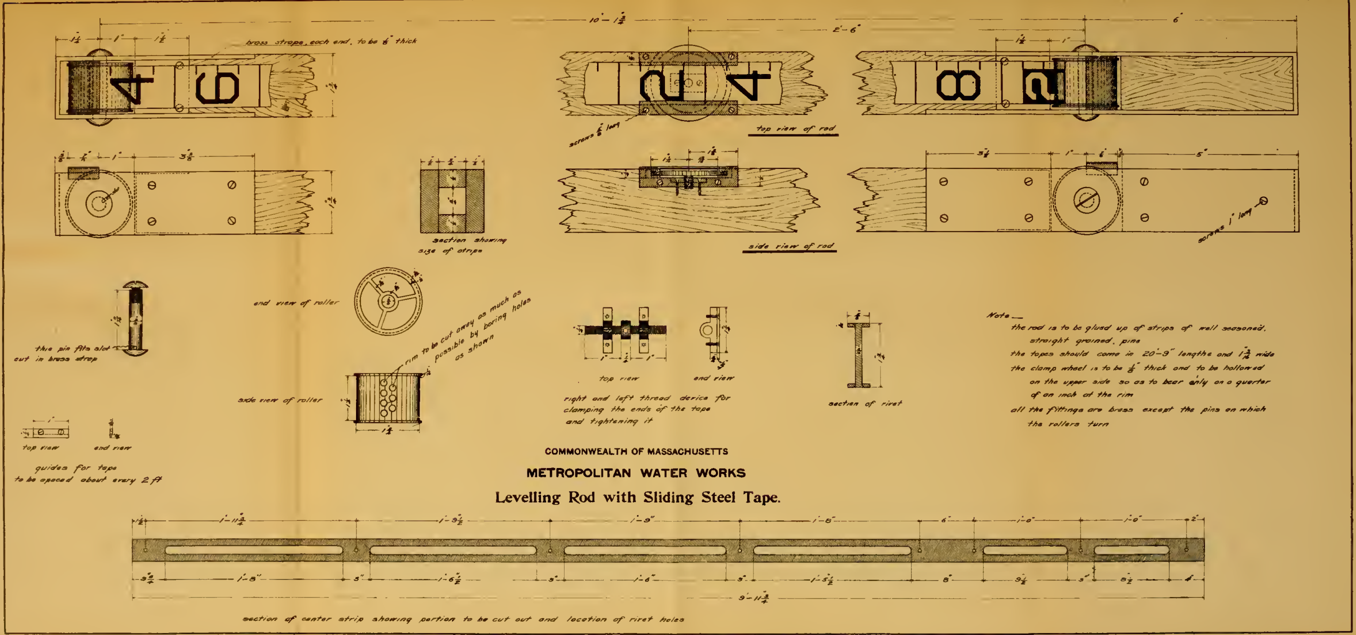
The parties on this work consist of five members—assistant engineer, instrumentman, two rodmen and an axman. When taking levels two rods are generally used, and in level country three are often used to one instrument. For running bench levels, tested Boston and New York target rods are used. A self-reading rod with sliding steel tape is used for all levels for estimates. With these rods the actual elevations are taken and recorded in the field. The tapes are of steel, 1 3-16 inches wide and 20 feet 9 inches long, graduated to half tenths and easily read to hundredths.

The level is set up at any convenient point from which a rod reading can be obtained on a bench of known elevation, and the tape moved until the reading coincides with the units, tenths and hundredths of the bench elevation. The tape is then clamped and any readings taken from that set up give actual elevations, the recorder supplying the figures of the hundreds and tens column. The exposed part of the tape on the face of the rod is two or three hundredths more than 10 feet, and the sliding range is such that any graduation from 0 to 20 feet can be exposed so that it is possible to properly set the tape for any set up from which the rod can be seen.

It is especially important that the sliding tapes should be made perfectly true and not kinky on the edges and with proper elasticity; otherwise they will bind in the guides or on the rollers. I believe that it has been necessary to import these tapes, those obtained in this country proving unsatisfactory in these respects. The first tapes used were enameled and graduated by the manufacturers, but a day's use removed half the enamel by cracking it in passing over the rollers.

After a second unsatisfactory trial of enameled tapes, we have found it best to paint and graduate them ourselves, using a pure white lead paint and covering with colorless varnish. Tapes coated in this way will stand active use for two or three seasons without repainting. The principal wear to these rods was from rattling about in the field teams, and this is now prevented by providing each field team with a padded rack on the tail board, into which the rods are dropped and held securely. A set of brass stencils are used for graduating the tapes.

A longer rod would often be an advantage on steep ground, but this advantage would be offset by the liability to 10 feet errors and the increased weight.



COMMONWEALTH OF MASSACHUSETTS

METROPOLITAN WATER WORKS

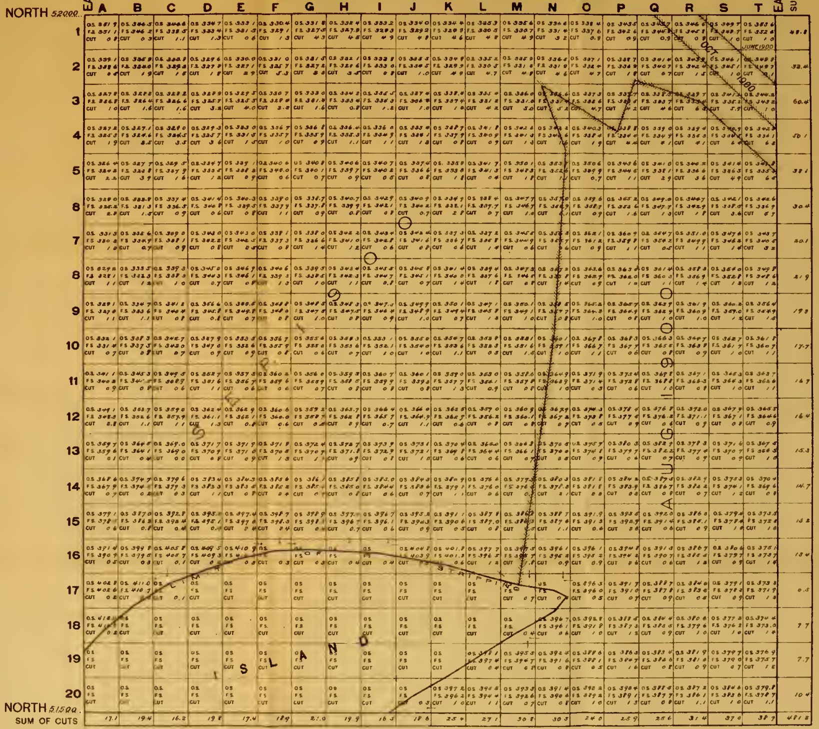
Levelling Rod with Sliding Steel Tape.

COMMONWEALTH OF MASSACHUSETTS

METROPOLITAN WATER WORKS

WACHUSETT RESERVOIR, REMOVAL OF SOIL

Cross Section & Estimate Sheet for Square No. 606



FINAL ESTIMATE COMPUTED BY
" " CHECKED BY
" " CHECKED AT DEPT. OFFICE BY

O.S. NOTE BOOK NO. 13
" " "
F.S. NOTE BOOK NO. 18
" " "

NOTE: "O.S." MEANS ORIGINAL SURFACE, "F.S." FINISHED SURFACE ELEVATIONS TO BE TAKEN IN THE EXACT CENTER OF THESE SQUARES & ENTERED TO THE NEAREST TENTH OF A FOOT

ESTIMATES

Contract No. 166

Section 6

KIND	DATE	SUM OF CUTS	CU. YDS.	CERTIFIED TO BY
MONTHLY	JUNE 28, 1900		28	
	AUG. 28, 1900		1944	
	SEP. 10, 1900		11072	
FINAL	OCT 8, 1900	481.2	11139	

The rods are especially suited to this kind of work, which requires a very large number of elevations compared with the volume of excavation, but they have also been used on our road construction and largely for setting grades and making estimates at the dike. These rods, as first made, weighed from 14½ pounds, made of pine, to 19 pounds, made of maple. Modifications have since been made, building up the staff so as to make a hollow rod and changing the clamp and tape rollers. The rod exhibited is of the latest pattern, and weighs 9¾ pounds. By the use of these rods all office reduction of notes is avoided and an immense amount of time saved.

During the early part of the work the cross-section notes were taken in the ordinary form of field book, but for convenience and economy of space a new form was adopted, as shown. The pages are ruled and printed in the same form as the estimate sheets, and the elevations are recorded as taken in the field, each in its proper square. Separate pages are used, however, for the original and final surfaces.

The space at the right of the right-hand pages is used for recording bench elevations, turning points, etc. The limit lines of work for monthly estimates are located from stakes or by stadia and tinted on the estimate and progress sheets. Elevations for monthly estimates are not entered on the estimate sheets unless the stripping is completed at the points taken. Sometimes elevations only on skeleton lines are taken sufficient to give an average cut for the monthly estimates.

The outline of area stripped for monthly estimates is very irregular, as is shown on the progress sheet of Section 6, Nawn & Brock, contractors. This is the largest contract, requiring the excavation of 3,000,000 cubic yards of soil from nearly 1700 acres.

During the five weeks ending October 20, 1900, when, perhaps, the most rapid progress was being made in soil removal, 310,000 cubic yards were removed from 171 acres. Four contracts were in progress at that time, the average force being 1417 men and 294 horses, and 24 locomotives, 2 50-horse-power hoisting engines and about 21 miles of railroad were in operation. Four engineering parties, consisting of about 25 men, were employed on soil removal estimates at that time.

Owing to the variety of circumstances tending to modify the volume of carloads transported on this work, it was not believed that car measurement would be of much use even as an approximate check on estimates, and many comparisons which have been made seem to prove the truth of this theory. Record is made of

the measured capacity of cars and an account is kept of the number of carloads from each locality.

In arable lands, especially where there is a sod and the soil is shoveled directly into cars without previous plowing, the cars, although apparently well filled, contain comparatively small volumes (measured in excavation) owing to the voids between unbroken lumps.

When the soil is grubbed or plowed, shoveled into carts, hauled a greater or less distance and loaded into cars from hoppers or long chutes, it becomes thoroughly pulverized and much larger volumes (measured in excavation) are transported. Besides the different methods of excavating and loading into cars, other factors which tend to vary the relation between car measurement and volume in excavation are the thorough pulverization of soil when cast over several times down steep slopes, the loose turf or leaves sometimes burned after the original levels are taken, the roots and stumps below the original surface which are burned on the ground and never transported and the rivalry between foremen on secondary lines in their attempts to make a good record in number of cars.

DISCUSSION.

Mr. N. S. Brock.—During the past six years the firm of which I am a member has excavated, under various contracts, about 4,000,000 cubic yards of soil from the Metropolitan Basins. This soil has been measured by the various methods described in Mr. Hart's paper. The larger portion, however, has been measured by the method of 25-foot squares. I have been in close touch with all details of the work, and can testify, from the point of view of the contractor, that any one of the three methods seems to give a satisfactory result. It is understood, of course, that the methods are approximate, as, indeed, are all methods of earth measurement, and depend on the balancing of errors for whatever approach to accuracy they attain.

It seems to me, however, that in measuring material, the price of which ranges no higher than does that of earth excavation, the engineer would perform his full duty to both employer and contractor, and, indeed, entirely fulfill his professional obligations if he adopted that one of the three methods which proved to be the least expensive.

Even admitting the possibility of the errors not balancing, we add only one very remote risk to the contractor's many greater ones, and one which he can safely disregard, since he has much more than an even chance of winning.

It has not been stated, but is, I think, true, that on the work with which Mr. Hart was connected the method of 50-foot sections was not considered sufficiently accurate for measuring borrow pits, since these, in the nature of work, cover much smaller areas and are irregular in outline and in depth.

Also, since excavations of this character are usually made to an approximately plane surface, and do not follow, as does the soil stripping, the general contour of the original surface, the errors due to irregularities of the surface between levels are considerably increased, and the balancing of these errors becomes a greater factor in the problem.

In estimating the volume by 50-foot sections Mr. Hart has used the even hundreds and the + 50 sections; the result by combining the + 25 and + 75 sections could be easily obtained and would be interesting.

Mr. W. W. Patch.—Mr. Hart suggests that, in the matter of relative expense for engineering, there might be considerable difference whether measurements were made on the basis of 25-foot profiles or 50-foot profiles. While serving on the engineering force engaged on the Sudbury Reservoir construction, I had occasion to measure work under both methods, and hence I can contribute some data bearing on this question.

The engineering parties, as organized for that work, consisted generally of four or five members, and were each responsible for the work on about 200 acres of reservoir stripping and embankments, and also in many cases for a certain amount of highway and masonry construction. The taking of profiles at 25-foot intervals rather than 50 feet apart would necessarily nearly double the field and office work connected with the measurement of excavation; but, as the estimation of quantities was probably not over 50 per cent. of the work required of a party, and as the amount of work that can be accomplished by a field party is often largely determined by the necessities of the case, the actual increase in the cost of the 25-foot profiles did not add more than 15 per cent. to the expense of an engineering party.

The fact that Mr. Hart finds the shrinkage of excavated material to be about 82 per cent. recalls an interesting feature connected with the construction of some of the embankments made with materials excavated from swamps. The muck removed from the largest swamp on the reservoir site contained from 20 to 90 per cent. of organic matter, as determined by the loss on ignition of a sample dried at 100° Centigrade. Embankments 8 or 10 feet high, made with this muck, were built as "end dumps," using cars hauled

by a locomotive on a track supported by planking along the edge of the top of the fill. The grade stakes were set to allow for a settlement of 33 per cent., and this has been realized in many cases. As the material dried out, large cracks would open for a depth of several feet, and if by accident the embankment caught fire, it would burn most persistently and was extinguished with great difficulty. One embankment near a highway, which had been built two years, was ignited, probably from a cigar butt, and defied all efforts to extinguish it until the fire department of the town of Southboro had drenched it with water for half a day.

I believe the method of 25-foot squares would show a decided gain in accuracy over the method of profiles in some kinds of ground. I have in mind a section of tussocky swamp well covered with water, where, if the area had been cross-sectioned by the method of 25-foot squares, the points on which the rod was held would be definitely fixed, thus largely eliminating the personal error of the rodman. I have found by experiment that on a profile one mile in length, on ground of this character, the average elevation as obtained by two experienced rodmen might differ by 0.2 of a foot, which would mean a difference of 4 per cent. for a 5-foot cut. It was common practice in swampy ground for the rodman to select the place for setting the rod and then to hold the latter on the toe of his boot to prevent its settling while the reading was being taken.

Another advantage possessed by the method of 25-foot squares is that it obviates the necessity of plotting cross-sections and of using a planimeter in computing areas. In estimating extensive excavations this latter method is very tedious and trying for the eyes, although admitting of a high degree of accuracy.

Mr. H. A. Miller.—I was glad that Mr. Patch brought out the question of personal judgment of rodmen, as that was one of the factors that made us use the 25-foot square method; no one was to use any judgment as to points where levels should be taken. Where the stake came the level was to be taken, leaving no chance at all for averaging. From records which we are accumulating, I think we shall be able to show clearly at how much greater distances apart it will be proper to take levels when measuring a large area than when measuring a small one. The reason why one would not measure a borrow pit by profiles 50 feet apart is not because the excavation is deeper. The error is not increased or decreased by difference in depth of the excavation. A borrow pit is of comparatively small area, and is left by the contractor with steep slopes, so that the final surface has abrupt changes of eleva-

tion. It does not make any difference whether the average cut is 1 foot or 50 feet. The error consists in the difference between the assumed and the actual original surface and the difference between the assumed and the actual final surface. I have been deeply interested in this paper, as I have been largely employed upon similar work on the Wachusett Reservoir at Clinton.

Before I started work there, I made a very careful study of the methods that should be adopted on work extending over large areas.

I want to call your attention to one or two theoretical considerations in regard to measurements. The author states that he took levels on the corners of his 25-foot squares. I suppose that was because it was more convenient to do so, as the points came on the regular profile lines. He did not add anything to the accuracy by taking levels at the corners of the squares instead of at the center, because if the levels are taken a certain distance apart it makes no difference where they are taken.

When taking a level on four corners of the square and taking one-fourth of the level on each corner, to determine the elevation of that square we use one-fourth of the elevation in each one-fourth of the square. We might just as well use one-fourth of the center elevation at the diagonally opposite corner of the one-fourth of the square; that is, instead of taking one-fourth of the elevations at each of the four outside corners to determine the elevation of these four quarters of the original square, we might just as well take one level in the center of the square, and one-fourth of that will just as accurately determine the elevation of each one of the four quarters of the square.

For the purpose for which the measurements were taken, on which this paper was written, it was necessary to assume the standard which has been assumed; that is, the 25-foot profile method. That, however, is an assumption that with that method the measurement is absolutely accurate. Of course it is not. The error may be less than that of either of the other two methods, but there will be some error.

Now, suppose we make a comparison of the relative accuracy of the 50-foot profile method, the 25-foot profile method and the 25-foot square method. I assume that the accuracy of the measurement is in the inverse ratio of the average distance of the center of gravity of the area measured from the points at which the levels are taken. Assuming that the 25 and 50-foot profiles are accurate, so that they represent accurate sections of the ground, the distance from the centers of gravity of the areas measured to the points at

which the levels are taken by the two methods will be in the ratio of 1 to 2. The distance from the center of gravity of the area which is measured by the 25-foot square method to the points at which the levels are taken has the same ratio to the distance from the center of gravity of the area measured by the 25-foot profile method from the points of measurement as the side of the square has to the diagonal; that is, 1 to 1.41; but, instead of calling the ratio 1 to 1.41, to simplify it we call it 1 to 1.5. The different methods, therefore, have approximately the following degrees of accuracy:

$$\begin{aligned} \text{25-foot profile method} &= 1 \\ \text{50-foot profile method} &= \tfrac{1}{2} \\ \text{25-foot square method} &= \tfrac{1}{1.5} \text{ or } 1 \div 1.5 \end{aligned}$$

or, to avoid fractions:

$$\begin{aligned} \text{25-foot profile method} &= 6 \\ \text{50-foot profile method} &= 3 \\ \text{25-foot square method} &= 4 \end{aligned}$$

In apportioning the errors to determine what the probable quantities are, we ought, therefore, to give the 25-foot profile method a weight of 6, the 50-foot profile method a weight of 3, the 25-foot square method a weight of 4; that is, the 25-foot square method is more accurate than the 50-foot profile method and less accurate than the 25-foot profile method. After I had determined the weight which should be given to these different methods, I analyzed Mr. Hart's Table No. 1, except that I used areas instead of percentages of quantities. I think that is more accurate, because, as I have already stated, the error depends on the area from which the soil is removed and not upon the quantity of soil removed.

In his Table No. 1, taking the same assumption he does, that the 25-foot profile method is accurate, we find that on his first area of 2.68 acres there was an error of 127 cubic yards by the 50-foot profile method, and by the 25-foot square method of 67 cubic yards. In the second area of 3.88 acres there was an error by the 50-foot profile method of 72 yards and by the 25-foot square method of 29 yards. In the third area of 4.32 acres there was an error by the 50-foot profile method of 109 yards and by the 25-foot square method of 80 yards. In the fourth area of 3.53 acres, by the 50-foot profile method an error of 62 yards and by the 25-foot square method an error of 60 yards.

Now, the average area of those four areas is 3.6 acres, and the average error by the 50-foot profile method is 93 cubic yards, and by the 25-foot square method is 59 cubic yards, an average error

per acre of 26 and 17 cubic yards, respectively. Some of the errors are + and some are —, and they balance to the extent that the total error on the whole 14.41 acres is only 8 cubic yards by the 50-foot profile method and 18 by the 25-foot square method; an average error of about 1 cubic yard per acre, as compared with errors of 26 and 17 cubic yards when areas averaging 3.6 acres are measured.

This shows that when large areas are measured less frequent levels are needed than would be required on small ones.

Suppose we fire a bullet at a target; we are not good marksmen; we come quite a distance from the bull's-eye. Suppose the bull's-eye were erased; it would be absolutely impossible from that one shot to re-locate it; but, if we kept on shooting for a day or two, by getting the locus of the shots we could from them determine and re-locate substantially the position where the bull's-eye was originally placed, provided there were no constant errors, as, for example, a wind blowing constantly from one direction. And it is somewhat the same way from these levels. The question of the accuracy of the measurements depends not mainly on the distance apart from which the levels are taken. It depends on that partly, but mainly on the size of the areas which are measured, because the large areas give a multiplicity of levels.

One thing more: I deduce, as I have stated, from these theoretical considerations that the 25-foot square method is more accurate than the 50-foot profile method. The indications that Mr. Hart has noted, taking some areas that are not given in his tables, show that the 50-foot profile method was more accurate six times out of ten than the 25-foot square method. I think that is due to this, that he has combined his two methods; that is, he did not move over 12½ feet to get 25-foot profiles, which would be entirely different from those he used in his 50-foot profiles, and, therefore, his 50-foot profiles were used over again with his 25-foot ones, and, while his results would show that his 50-foot profile method is more accurate than his 25-foot square method, if he had taken entirely new profiles I think his results would have shown that the 25-foot square method was the more accurate of the two; in other words, that the accuracy of the measurement depended on the nearness of each level to the center of gravity of the area measured by that level.

The system in use on the Wachusett Reservoir obviates, so far as practicable, the exercise of personal judgment by the members of the engineering staff and to that extent removes the errors due to defective judgment. The 500-foot squares are divided in a

certain way into 25-foot squares, with a stake in the exact center of each square. Where the stakes are set the levels are taken. The engineer reads an elevation and enters it in a notebook, where there is only one place on the page for any elevation to go; he has in his office on a computation sheet just one place where that elevation goes again, and if he puts it in the wrong place in the field book or on the sheet, before he finishes the page or the sheet, he finds it out. When he is through taking his levels in the field, he has his elevations recorded where they ought to be. When through transferring them to the sheet, he has them where they ought to be.

Mr. E. P. Adams.—In taking levels over small areas we have used the 20-foot squares, because it was a saving in the figuring; simply added the cuts or fills and it gave us the cubic feet of the cut or fill, because the 400 square feet in the square divided by four makes 100 feet. Although, of course, we would have over 50 per cent. more levels for the 20-foot square, there is a saving of the calculations, which amounts to considerable in a great deal of figuring.

Mr. Miller.—We took the 25-foot square because it divides the 100-foot square into four equal parts, and because we thought that was sufficiently accurate. And in anything over 5 or 10 acres measured that way the measurements are adequately accurate.

Mr. Brock.—Of course, every time that you run over one corner to another of the 25-foot square you cut off a slice on an outside curve, and unless you balance that by a re-entering curve, you are going to conflict constantly. It seems to me that the 25-foot section method is nearer than the 25-foot square method or the 50-foot square method. I am thinking of a hill which has not been entered at all. It has a rounded surface, and, of course, you may lose a slice. If it was a very large surface, including hills and valleys, I will admit that it might be nearly as accurate one way or another.

Mr. Miller.—If you remove a mound-shaped hill you always lose the difference between the tangent and the arc, and the levels should be taken close enough together to reduce that difference to a very small quantity. Of course, if you had a borrow pit, where you got a general average of surface,—an equal amount of concave and convex surfaces,—then the result would be just as accurate in a borrow pit as on soil removal.

Mr. Hart.—The reason why in the paper we used our 25-foot strip as a unit is because we had taken more elevations on those lines than any other, and they are entitled to precedence on that

account. We didn't suppose that the standard was an accurate standard.

Mr. Miller.—As I understand it, Mr. Hart wanted to show that his 50-foot profile method was all right. Now, when assuming that the 25-foot profile method was accurate, he assumed that the 50-foot profile method contained a larger error than it actually did contain. The actual quantity would probably lie between two measurements of an area, and I think it is safe to assume that on those 14 acres it lies between the two extreme measurements.

Mr. Hart.—On mathematical grounds, I do not think we would say that exactly. It might be that both were not quite accurate. The practical deduction is that for large areas of this kind of work there is no choice between the methods so far as the contractor is concerned. The larger the area the smaller the error, because there is more opportunity to balance, and a very large area will annihilate the error. It makes no difference whatever, mathematically, whether you take the four corners or the middle of the squares.

Mr. Patch.—Can we get the same accuracy in measuring a 10-acre lot with 50-foot square or profile method as with a 5-acre lot with 25-foot profiles or squares?

Mr. Miller.—I think that the percentage of error in measuring a 10-acre lot by the 50-foot profile method and a 5-acre lot by the 25-foot profile method would be the same, and that the percentage of error in measuring a 20-acre lot by the 50-foot square method and 5-acre lot by the 25-foot square method would be the same. What I wanted to bring out was that when you are measuring up any large area of soil stripping all of the methods under consideration will give the same results.

Mr. Charles E. Wells.—Referring to car measurements, as compared with measurements of soil in place, I may remark that on Nawn & Brock's work several methods were employed in breaking up the soil previous to loading it on the cars.

On light stripping of meadow land the soil was sometimes plowed, the plow running about to the depth of the excavation. The sod, left in furrows by the plow, was cut in pieces about 18 to 24 inches in length by the shovelers and cast on the cars. Loose material was then cleaned up and loaded.

Sometimes, on light stripping of meadow land, the sod was spaded by the shovelers, each shovelful being thrown directly on to the cars, and cleaning up would follow. Material loaded as described would consist largely of sod, which would not lie com-

pactly in the cars, and, therefore, a minimum amount of soil would be placed in each car under such conditions.

On deeper meadow excavations the proportion of sod, as compared with the total volume of excavation, would be less, and a proportionately larger amount of material, as shown by measurement in place, could be loaded on each car.

When the original surface was covered with a growth of brush, the ground was first cleared, and usually the soil was broken up with mattocks. The small stumps and roots were grubbed out and placed in piles and burned before the operation of soil excavation was commenced. Soil was generally grubbed to the depth of excavation and was pretty thoroughly pulverized. It was then shoveled on to dump carts and hauled to the loading platforms or chutes and dumped into cars. The different operations of grubbing, shoveling and dumping of the soil had a tendency to render the soil more compact by the time it was finally loaded into the cars.

Car measurements and measurements of soil in place compared the most favorably by this method of handling soil.

On steep slopes the soil was broken up with mattocks and small stumps and roots were grubbed out and burned. The soil was then cast down the slopes, sometimes requiring to be shoveled over several times before reaching the bottom of the slopes. It was then shoveled on to the cars. The operations of grubbing and repeated casting down the slopes had a tendency to compact the soil even more than when it was transferred in carts and dumped into cars.

Mr. E. S. Larned, C.E.—I wish to express my pleasure in having an opportunity to be present at the reading and discussion of Mr. Hart's paper. It was my privilege to be connected with this work, later having direct charge of construction in the Sudbury department under Mr. Desmond FitzGerald.

The circumstances leading up to the special investigation covered by Mr. Hart's paper were very familiar to me, arising primarily from the claim of contractors that the system of measurements in use did not correctly give the amount of material moved and to be paid for. This claim was based largely on the result of car measurements, observed by the contractors in rather an unscientific and unsystematic way, and was further strengthened by the disappointment occasioned by unprofitable work.

For the successful conduct of engineering work it is very necessary that the contractor should feel a confidence in the correctness and impartiality of the measurements taken as a basis of

estimate for payment, and this good feeling is greatly promoted by a cordial and candid understanding of the methods in use from the very beginning of the work, and by placing the records at the contractor's disposal for examination and suggestion, if desired. It must be granted that methods or systems of measurements should be as correct as science or the character of the work admit, or, if only rough approximation is called for, there should be a previous understanding and agreement between the engineer and contractor before the work is entered upon.

The results given in Mr. Hart's paper are instructive and suggestive. It is not uncommon to find hard and fast rules followed in earth measurements without proper consideration of their cost or value.

The results of careless field work cannot be corrected by exact office computation.

In determining the relative engineering cost of the three methods under discussion much depends upon the extent and character of the area considered, the organization and progress of the work and the variety of detail to be looked after. I do not think any comparison between the Sudbury Reservoir method of 25 and 50-foot profiles and the Wachusett Reservoir method of 25-foot squares, described this evening, should be made; the conditions are entirely dissimilar. At the Sudbury there were seventeen contracts for stripping, many of them subdivided, and shallow flowage treatment was a feature of this work, involving much detail. Seven small engineering parties of about four men each were required to look after this work, and, as may be well understood, the organization of the contractor's force was variable and progress irregular. The same engineering force might have cared for much more extensive work well organized and systematically prosecuted, but no reduction could be made under the conditions presented.

The Wachusett work had the advantage of much larger area, larger force, better organization and less detail involved by shallow flowage treatment.

I believe I am right in saying that the use of 25-foot squares at Wachusett was largely the outcome of Mr. Hart's investigation of the three methods as applied to the area considered at the Sudbury, it being assumed that for the large area to be treated this system would give satisfactory results and greatly simplify and reduce the cost of the engineering work. This would appear to be so, and, inasmuch as the system was described and incorporated in the contract specifications, there would seem to be no ground

for dispute on the part of the contractor. We had in the Sudbury Reservoir a large swamp, from which the material was removed by suction dredge to a maximum depth of 10 feet. During the progress of this work estimates were based on the average of soundings taken from the dredge during the day, and the area excavated determined by stadia. At the completion of the dredge work the basin was pumped out and the shores thoroughly cleaned out to the line of 10-foot cutting. This was immediately cross-sectioned for final estimate, but, owing to the soft nature of the material beyond this line, in many places 30 to 40 feet deep, and incapable of supporting a man, it was necessary to allow the basin to refill and wait for winter, at which time soundings were taken through the ice at distances 10 feet apart on the regular cross-section lines. The water remained at almost constant elevation, but gauges were set at convenient points and the water level taken three times each day. It was necessary to put a foot-block 6 inches square on the sounding rod, to prevent its sinking into the soft mud under slight pressure, and the rod was counterbalanced to overcome buoyancy at the average depth of water, about 10 feet.

Mr. Miller.—We had in Chicago a special rod made of maple, with iron strips, so adjusted that the flotation was balanced as nearly as possible at all depths of water, and we had a large disc on the bottom of the rod full of holes. We would let the rod down carefully, and when it stopped sinking we would take the reading.

Mr. Frank A. Bayley (by letter).—I have always considered the method by sections particularly adapted for long and comparatively narrow valleys, where the side hill slopes form quite a per cent. of the whole surface and where the bottom lands are more or less broken ground.

On flat open land the method by squares may give as good results, but even in this case I should prefer the sections.

I am surprised to see how closely the result of the method by squares agrees with the others in the experiments, although, as I remember the ground covered, I should call it highly favorable for the method by squares.

Of course, in theory the closer the ground is covered the closer to the truth will be the result, and hence one would expect the 25-foot sections to be much closer than 50-foot sections; but I have always considered 25-foot sections impracticable on areas of any size, as they take more time to run over than can be given in the few days usually allowed in making up a monthly estimate.

I have always believed that the 50-foot sections gave almost as good results, with much less labor and time, but I had no idea, until this paper was read, how little difference there was.

The method we have used in practice must be even closer, if possible, as we have been in the habit of interpolating sections at 25 feet whenever we thought them needed to give proper results.

In this way one can cover a hole which occurs between 50-foot lines.

Sometimes these extra sections are needed in the preliminary work, but mostly will come when the stripped surfaces disclose extra depths, of which the surface gave no warning.

These auxiliary sections were made only long enough to cover the trouble and were introduced as seldom as possible.

The sections being approximately normal to the axis of the valley will ordinarily resemble each other quite closely.

On the other hand, in the method by squares, the shots are taken at fixed points, and may or may not represent the actual conditions of the ground; on slopes of hills and broken ground around brooks and swamps, probably will not.

After all, in any method, a great deal depends on the judgment of the rodman in choosing his spots to rest his rod, and a well-trained rodman is absolutely necessary for good results.

Mr. Frank S. Hart.—Reference has been made to the circumstances occasioning the investigation which furnishes the subject of the paper.

I am not well enough acquainted with the criticisms and complaints mentioned, or with the pressure brought upon the engineer in charge in the way of contention about the best methods of measuring, to offer any statement concerning them, but I was fully impressed with the fact that the engineer, Mr. FitzGerald, had positive confidence in the practical accuracy of the 50-foot strip method and was willing to have the tests and comparisons severe and rigorous.

I am very sorry that his health has been such lately as to render him unable to be present or to take part in the discussion, and also that it was inadvisable to postpone the presentation of this paper until such time as he might be able to show his interest and offer his contribution.

I also regret that the chief engineer of the Metropolitan Water Works, our past president, Mr. F. P. Stearns, who was well acquainted with the investigation during its progress and had considerable interest in it, sends word that he is not able to be present this evening.

As intimated in the paper and referred to during this discussion, the work by the different methods was so thoroughly mixed with the regular work that no possible identification and separation could be made that would give any idea as to the proportionate time required for each method, not to say the actual time spent on each. Nor were the conditions such that, could these facts have been determined, would they have had any value to apply to other cases or to the general run of cases.

Mr. Miller will no doubt be able to tell us, when the Wachusett Reservoir is completed, what the cost has been per cubic yard of stripping and per acre stripped due to the item of "measuring," and with comparative ease, for he has no complication of methods or other troubles, as has been pointed out by Mr. Larned.

It would be interesting to us, I think, if some equally reliable figures could be had of the measurement cost of a similarly large area measured in 50-foot profiles and another in 25-foot profiles, with the same high order of organization and system that has obtained at the Wachusett Reservoir applied in each case, so that all of the conditions and circumstances should be practically the same.

For comparison of methods as regards satisfactory and reasonable accuracy, I suppose that the broad principle of the eventual balancing of errors when any indefinitely large section is treated obtains here in its fullest extent, and any one of the methods carried out fairly will give results equally acceptable to the contractor and engineer.

The investigations of the paper indicate that for the particular areas selected there was no choice.

Mr. B. F. Goodnough, a fellow member, has handed me a few figures of work done recently on the borders of Lake Cochituate, which are interesting. He found that the stripping from a 7-acre section at Snake Brook Meadow was 16,727 cubic yards measured by 50-foot strips, while 25-foot strips made it 16,666 cubic yards, the ratio being 1.0036 to 1.0000. In another case he found the stripping from an area of 37.35 acres at the Pegan Brook Meadows to measure 147,757 and 147,720 cubic yards, respectively, by the 50-foot and 25-foot strips, or a ratio of 1.0002 to 1.0000, and here also there was evidently no choice,

Mr. Miller speaks of the errors as being independent of the average depth of the cutting or soil-stripping, whether it was 5 feet or 50 feet. Yes, the error in cubic yards would be the same, but the proportionate error would be very dependent on the average depth, and with a great average depth might be properly ignored,

when, were all other conditions equal and the depth quite shallow, the errors would condemn the method.

If we take our elevations to the nearest tenth of a foot, we have right here an error, in the case of an average depth of 1 foot. stripping, of from plus 5 per cent. to minus 5 per cent. for each surface, but if the average depth is 10 feet, this range of error decreases to, from plus $\frac{1}{2}$ per cent. to minus $\frac{1}{2}$ per cent. If, in the long run, in the first case the errors balance, there is no room left for dissatisfaction for cases of greater average depths. The first case is the case of the investigation, the case of soil-stripping as practiced on water supply reservoirs.

Mr. Miller also spoke of the prejudice involved in the comparison of the 50-foot strips with the 25-foot strips, where the profiles of the 50-foot strips are used over again with those intermediate between them to complete the set of 25-foot profiles. If he will take the following view I think he will see that there is really no prejudice affecting the comparisons: Suppose the profiles 50 feet apart are worked up and results obtained, and the question is asked, What difference will be shown if the 25-foot profiles are added? What gain in accuracy is indicated? Well, we show that no matter what the standard is, whether 25-foot squares or some unattainable hypothetical refinement which shall be unquestionable and unquestioned, we get about as near to that standard by the one method as by the other, the differences balancing because of their different signs and the conclusion being that the 25-foot profiles were not needed.

We might have continued our work further, as suggested by Mr. Brock, and made a second set of 50-foot strips, using those profiles not used in the first set. I should not expect to get aggregate results different from what we have already shown.

As the practical cases integrate, may I use the expression, all of the different conditions involved and give each its due weight, there is not as much demand for or importance attached to the discussion and expounding of the mathematical principles governing the comparisons. Yet, as they have been referred to and used to some extent in the discussion, I may be pardoned if I offer a few thoughts and suggestions which may be pertinent to the subject.

In the first place, the 50-foot profile is supposed to have had enough elevations taken in making it to make it a substantially accurate representation of its whole length, and to be so near the truth that no more elevations would be needed.

The 25-foot profile is, of course, of the same accuracy in itself, and its comparison in weight to the 50-foot profile is commonly

set as inversely to the areas in arithmetical proportion. It has been suggested, with some apparently plausible reasoning, that the proportion is of a higher degree, but we will accept the usual view.

Now, if two sets of these profiles, instead of being determined as above, had been determined by independent points 50 and 25 feet apart, respectively, by the same reasoning we should say that they had a relative value of 1 to 2, and if in a third set the independent points were only 5 feet apart, the profiles containing them would accordingly have a value of 10; what value then shall we allow to those profiles whose points are so selected as to represent an almost continuous line of points (or locus of a point moving along the surface)?

In the second place, the 25-foot squares with elevations at the centers are the same as 25-foot squares with elevations taken at the corners, as Mr. Miller has so carefully explained, and 25-foot squares with points taken at the corners will afford parallel profiles 25 feet apart with points taken 25 feet distant from each other, which suggests a condition of comparison with other profiles taken 25 feet and 50 feet apart, as referred to above, and we simply repeat the question, What relative values shall we allow to two profiles, one with points 25 feet apart, regardless of undulations, and the other with points sufficient to represent, more or less accurately, those undulations? The intimated answer is not satisfying, I admit.

If the errors are all going to be one way, or if the signs of the errors were to be neglected, and if the undulations were to be of all possible varieties, we might have some such comparisons as are just suggested.

I do not know just how an expert in the use of the theory of probabilities would attack this problem. There are so many complications involved in an actual case that I should suppose the values of the results obtained would themselves be subject to similar treatment and would not compensate the investigator for his efforts. But I will dare to suggest a broad view of the subject that may be interesting, and possibly lead some of the competent ones to further and better conclusions than I am able to offer at this time in this line of analysis.

I first suggest this general principle, that in comparing different methods actual errors are likely to happen in the same proportion that the maximum error can happen. For instance, if in two cases the maximum errors that can happen are 10 and 30, then the actual errors will probably be in the proportion of 1 to 3.

I apply this principle to our subject in the following manner: Assume an area cross-sectioned by parallel lines 25 feet apart, with

points on these lines indicating 25-foot squares. Now, with, say, a slope of 2 to 1, how much material can be heaped up on this area, if level, without covering, in the first case, any point on the lines 50 feet apart; in the second case, any point on the lines 25 feet apart, and in the third case any of the points indicating the corners of 25-foot squares?

It is evident at once that two times the amount can be placed on an area between the 50-foot lines that can similarly be placed on the same area between 25-foot lines, and that more can be placed on the same area with 25-foot squares than with 25-foot profiles.

For an area of 10,000 square feet I make the quantities as follows:

For 50-foot strips, 62,500 cubic feet;
For 25-foot strips, 31,250 cubic feet;
For 25-foot squares, 47,780 cubic feet;

or in proportion of 2 to 1 and 1.53, which is in the neighborhood of what Mr. Miller has figured out by his method of analysis.

The assumption of a level plane on which to heap up these maximum additions allows for the greatest possible quantities in each case, and it is evidently also true that if the opposite condition was assumed, viz, the taking away of as much as possible of material from the area, leaving the slopes 2 to 1, and not disturbing the lines of the profiles or the corners of the squares as the several cases may call for, the quantities removed would figure out the same as above, with, of course, opposite signs.

The changing of the assumed slopes will not change the above proportions.

This conclusion may seem more acceptable than was the result by the former analysis, but when we settle down to a summing up of the whole matter, and take into consideration the condition that equal errors of opposite signs are equally probable, and that other conditions which might not be called errors are as likely to affect the results favorably or adversely with equal degrees of probability and magnitude, the whole resulting in a fairly well balanced estimate of the quantity of soil-stripping removed, we may agree with Mr. Brock that there are other more important conditions than ways of measurements to attend to, and the method which the engineer prefers and finds least expensive and best adapted ought to be satisfactory to all concerned.

RED RIVER VALLEY DRAINAGE DITCHES; THEIR REPAIR AND MAINTENANCE.

By Professor W. R. Hoag, Member Engineers' Club of Minneapolis.

[Read before the Club, March 16, 1903.*]

Very little constructed by the hand of man can be said to be permanent, and, though it be the promptings of an inborn desire to perpetuate his name or achievements, and though the reward of great wealth be promised for its success, yet man stands at the very threshold baffled and defied, and finds at best his work circumscribed by the limitations fixed by the inexorable laws of nature governing the materials with which he must construct.

True, he can cross the valley with a dam made of materials taken from the "everlasting hills," yet a Mill River or a Johnstown disaster records its complete and tragic passing. He can build bridges which will carry with absolute safety their loads for a generation or more, but it must finally yield either to the gradual deteriorating action of the elements, give way under some excessive load or be replaced by a new structure to meet new conditions with which it has become associated. He can build massive viaducts, with their solid masonry resting upon the granite hills, yet a single quake of nature and it falls in shapeless ruin, its very elements of stability proving its destruction.

This evident desire to build for all time manifested itself in the works of the earliest builders. The crumbling remains of ancient temples and monuments furnish us at once the proof of this longing to gain perpetuity and the futility of the attempt.

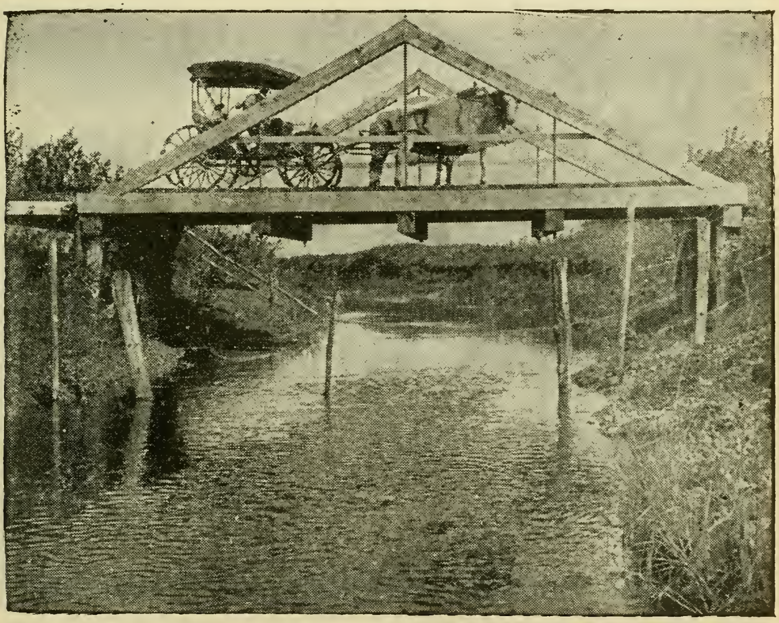
But why seek to gain that which is not only unattainable, but equally undesirable. The Pyramids might well have passed with the people that built them, for their remains are but grim monuments to the superstitious age which produced them. The granite obelisks have carried their message, and their hieroglyphics are gradually becoming obliterated, whether by the sifting sands of their native home or by the wasting gases of a New York, London or Paris atmosphere.

Every work constructed according to economic design under engineering supervision must satisfy the rigid conditions imposed by the commercial world, as well as those fixed by the material and forces with which it has to do. A means is to be provided for conducting a railway across a deep ravine. The engineer can readily present several plans for accomplishing this. He can use

*Manuscript received March 23, 1903.—Secretary, Ass'n of Eng. Socs.

a timber trestle on piling, costing, say, $100,000. He can make embankment approaches, using trestle for the central part, the whole to cost about $125,000; or he can substitute steel for the wood part, with a total cost of, say, $250,000. Again, he can construct it of stone, at a cost of $350,000; or, by introducing curvature and thus adding somewhat to the length of the line, he can avoid the ravine altogether, with a total cost of, perhaps, but $25,000.

Now, all of these plans would offer equally sure and safe means for the passage of trains. The last and cheapest in first cost would call for the largest annual charge to operate, together with small repairs. The wooden structure would bring a large



Felton Ditch, Clay County.

annual outlay in care and repairs, and in a duplication of the original structure, with the original cost, in a few years. The steel structure would cost but little in the item of repairs, and its probable renewal would be too remote to justify a railroad in giving it much consideration. The stone viaduct would necessitate no annual outlay, and its renewal would be very remote, even in the life of governments.

Now, what plan is best? Evidently there is no choice to the engineer who is to design and construct it, since there is no difference as to feasibility or safety. But there may be a wide range of choice to the company, State or government which is to pay the bill.

A company with small financial backing, whose bonds would not find a ready market, would wisely select that having the smaller first cost with the larger annual cost of maintenance, while a State or government would naturally incline to the other extreme.

Without tracing the controlling considerations which should govern in the selection of any design, which in turn will fix the cost and its probable length of usefulness, we believe it will be granted that small first cost does not argue a preference of design; neither does a long life of an engineering structure, of itself, constitute commercial economy; neither does small repair, or its absence

Snake River Ditch, Polk County, Showing the Confluence of the Polk County Ditch.

altogether, when considered alone, mean engineering excellence or business sagacity.

What is true of one engineering structure, in a large measure is true with all. The cost of repair, and, perhaps, ultimate renewal, must be considered, and is usually of controlling importance. Repairs are as legitimate as first cost or cost of operation. The engineer displays his skill as much in providing for the maintenance of his work against the harmful action to which it is subjected, or the natural deterioration of the material of which it is made, as he does in fixing the general features of the design.

The consideration of repairs will hold this importance in design as long as forces continue to be master over matter, or as long as it costs human effort to build.

The problem confronting the engineer who proposes to provide a more speedy removal of excess water from a piece of country presents no exception to the law referred to above. After the general geographical distribution of the ditches has been agreed upon by the constructing commission, since each drainage district or each county will seek some share of the benefits, the engineer must then determine where, of what size and of what length the several ditches shall be built. In fixing these important matters he must consider the probable behavior of the ditch in service, the

Tamarack River Ditch, Marshall County, Showing the Caving of the Banks. Eight Miles Long. Cost $20,000.

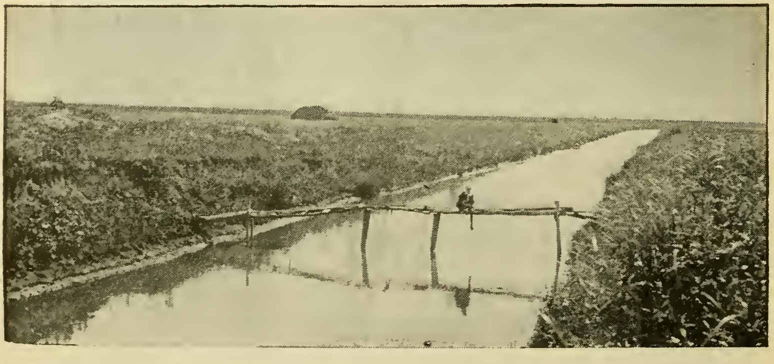
nature of the soil, the character and extent of the area to be drained, since all of these will have an important bearing upon the nature and cost of the repairs. For example, if the natural slope of the land along the line of the ditch is, say, 2 feet to the mile, a large area is tributary and a sufficient outlet is found, economy, both in less cost to construct and greater carrying capacity would suggest a deep and comparatively narrow ditch. This would give the maximum velocity of flow, and thus lead to the smallest deposit of sediment, which is likely to determine the subsequent efficiency of the ditch. On the other hand, if a comparatively short connection is needed to restore a lost watercourse through a swamp, a broad, shallow ditch would be best, since the slope of the ditch

usually will be slight and consequent depth small, and to gain the desired capacity it must be made broad.

That which claims our most serious consideration in the matter of repair of such ditches as we have in the Red River Valley is the combined action of sedimentation and vegetable growth in the bottom.

While yet the ditches are new and their bottoms are the hard clay underlying all this region, in which it is difficult for the perennials to get a start, comparatively little difficulty will appear from this cause.

But as this clay loosens under frost action and the natural erosive action of the water and is carried away by it, pockets will form, owing to the unequal action of each, as well as the varying consistency of the clay, which will be filled with loose alluvial deposit, affording the very best soil for native grasses.



Sand Hill River Ditch, Polk County. Thirteen Miles Long. Exerts a Beneficial Influence over at least 50,000 Acres. Cost $24,000.

It may require a half dozen years for this tendency to develop to any apprehensive stage in the majority of the ditches which have a sufficient slope, *i.e.,* from 3 to 5 feet to the mile.

Those having less than this, say from $1\frac{1}{2}$ to 3 feet per mile, have such a slight velocity that even the first season may result in a considerable filling up of sediment, and subsequent seasons bring a considerable growth of flags, rushes, arrow-wort and other aquatic plants.

The uninterrupted growth of these, of course, will soon terminate the usefulness of the ditch.

The choking up of the channel by the growth of flags and reeds is likely to be increased by the gradual drying up of swamp lands feeding such ditches, by lessened erosive action or by the

conversion of the grass land alongside into cultivated fields. A very dry season, completely drying out the ditch, might lead to a partial, or even complete, destruction of the aquatic vegetation.

These same conditions, however, especially the presence of cultivated fields, will bring conditions favorable to the filling up of the ditch with sedimentary deposit. This action is that requiring the closest attention, as it is most likely to finally limit the usefulness of the whole system.

While the ditches were new and the side slopes were unprotected by vegetation, those having a fall of over 5 feet on the mile, giving a velocity of three to four miles per hour, according to the depth of water in the ditch, excessive erosion has taken place.

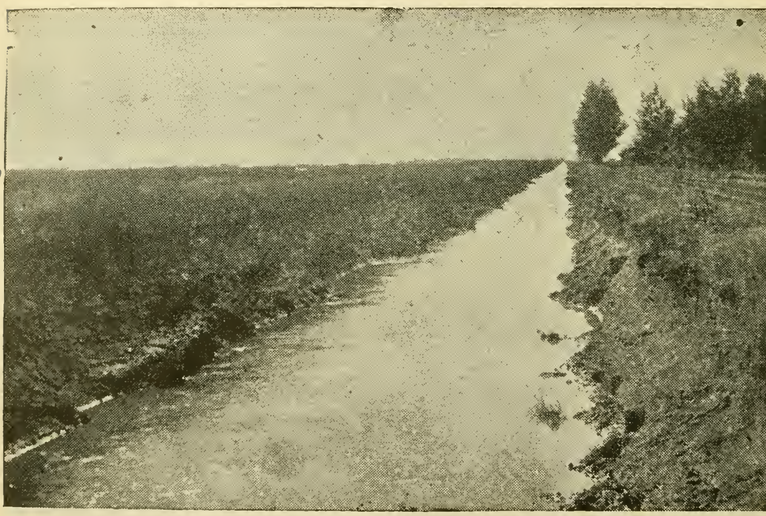
Spring Creek Ditch, Norman County.

With a slope less than 2 feet per mile, a still worse evil develops. The lower four miles of the Rabbit River Ditch, in Wilkin County, has a slope of about $1\frac{1}{2}$ feet per mile. This does not create sufficient current to prevent an accumulation of débris which comes to the ditch from the cultivated fields, and a filling up of the channel takes place. If the ditch is without water, except at flood season, vegetation soon gets a foothold, and then the usefulness of the ditch is at an end. The Mustinka Ditch, in Traverse County, is well advanced in this stage, and, until repaired, will not furnish full relief in time of flood. With these few exceptions, the ditches are enlarging gradually, as it was planned they should,

are fulfilling all expectations of the projectors and are contributing their full share to increasing the wheat area and general productiveness of the already famous Red River Valley.

If the ditch is to have a medium stage of water throughout the season, and for a long succession of seasons its repair will be comparatively simple and inexpensive, since vegetation is much less likely to gain a foothold and thus retard the flow of water in the ditch. If, in addition to a continued flow of water, the slope of the ditch is sufficient (3 to 10 feet per mile) to insure a fair velocity, the work of repair will be further simplified.

With the opposite conditions, viz, running water only at times of spring freshets and summer floods and such slope (1 to



Ada Ditch, Norman County.

3 feet per mile), the slight velocity will permit a considerable sedimentary deposit with each flood, which, together with the vegetable growth which is certain to spring up during the dry season, will, in a few seasons, seriously impair the action of the ditch.

No reliable tables can be constructed which will show the exact sedimentation which will take place with different soils of varying degrees of velocities of flow.

The conditions are not only much too numerous, but are themselves undefinable.

It is only by observing the exact behavior of each ditch, and by studying these seemingly unimportant phenomena from the first, that any scientific study can be made and any reliable knowl-

edge gained as to the best way and at the least cost these evils can be corrected.

There is still another class of obstructions which we have found much too common with the ditches in the valley. We have found occasional deliberate attempts to stop the flow of water, from a single board placed up edgewise across the bottom of the ditch to a well-made earthen bank nearly the full depth of the ditch. We have found the ditch completely stopped by hay, placed there to serve as a bridge. While these infractions of the law have not resulted from any hostility to the system, and the motives prompting them are good, yet it breeds a disregard for the ditches and is sure to bring ultimate injury to the whole system.

The heavy growth of weeds along the banks of the ditches, especially on the north side, will result in heavy snow drifts, which will remain in the ditch and be likely to prove a serious obstruction at a time when the ditch is most needed.

A word now as to what it costs to keep these ditches in repair. Possibly one-half of them have not been a dollar's expense to the county since they were made, in 1895 or 1896, if we except the matter of bridges. This cannot be offered, however, as proof that the next five years will bring no expense. On the other hand, it has cost over $200 to repair the damage to a single ditch occasioned by a single rain. Several ditches now require a few hundred dollars to remove the sediment and vegetable growth, and thus bring them to their former efficiency. In fact, it is safe to say that, compared to the original cost, to say nothing of a comparison to the great benefits, the item of repair is too small to justify being entered at all in the account.

THE RED RIVER VALLEY.

Nowhere within the boundaries of the State of Minnesota do we find such marked peculiarities as obtain in the strip of land 15 to 20 miles wide and 225 miles long bordering on the Red River of the North.

This tract of land, once the bottom of a large inland sea, is remarkable for its great richness of soil and is capable of the highest and most profitable cultivation. Its extreme flatness, however, and consequent absence of the natural means of riddance of storm water threatens, through frequent inundations, to discourage farming altogether or to render it extremely hazardous over considerable areas. Occasional severe summer rains drown crops already well started. These storms, however, occur only at inter-

vals of about five years, and are not the most serious obstacle to successful farming in the valley.

The tardiness with which the water from the winter snows and early spring rains drains off this extremely flat country, thus delaying the time of seeding by a week or ten days, is the great evil which attends this flatness of country, and to help correct which this State has wisely spent about a quarter of a million dollars in a comprehensive system of ditches for the valley.

We thus see that the State is here seeking to supply the one deficient condition for adequate storm-water drainage. It cannot actually supply the necessary slope to produce natural rivers across this level tract of land, but it can do the engineering equivalent. It can cut deep, straight canals across this territory, which will offer the least possible resistance to the flow of water and thus render the 2 or 3 feet per mile, usually available, quite sufficient to pass the water from the eastern slope to the Red River.

The first attempt to correct this evil, resulting from heavy rains and slow drainage, appears to have been made in 1879 by President James J. Hill, of the Great Northern Railroad. He built about forty-five miles of ditches, which were from 2 to 4 feet deep and from 4 to 6 feet wide.

They were from a half mile to three miles long, and were scattered through Kittston, Polk, Norman and Clay Counties. These earlier attempts at drainage were of but small local benefit, and at the time of the spring freshets and severe summer rains they were wholly unable to care for the flood water.

Without doubt much good was done by these small pioneer ditches, not the least of which was the object lesson they furnished to the farmers of what service even small drains could be. From the working of these they could easily see of what great benefit larger ditches would be, if they were of adequate size and were to begin somewhat to the east of the Great Northern track and extend to a sufficient outlet. Most of these ditches have now become filled up, some by natural processes, while others have been filled by the hand that made them. This was done to prevent further litigation on account of real or imagined damage done to the land along the line of the ditch, especially at its lower end, from water brought to it by the ditch.

THE PEOPLE TAKE UP THE WORK OF DRAINAGE.

The first practical move by the people interested to successfully solve this drainage problem was made in July, 1886, when a convention was held at Crookston to formulate a plan of united action.

At this convention Marshall, Polk, Norman, Clay and Wilkin Counties united and raised one-half of the ten thousand dollars needed to make a topographic survey of the territory. President Hill, of the Great Northern Railroad, donated the other five thousand for this purpose. Grant, Kittson and Traverse Counties later joined in the work.

The survey showed the need of about 275 miles of main ditches, costing about $750,000.

After repeated failures with the legislatures of 1887, 1889 and 1891 to secure an appropriation for this work, success finally was gained in 1893, at which time a bill was passed creating the Red River Valley Drainage Commission, or Board of Audit, and granting $100,000 with which to begin the work.

Of the conscientious work done by the friends of the cause during the eight years necessary to get legislative favor, very little has been written and little is known by the thousands of prosperous farmers whose chances for good crops have been increased tenfold through the untiring and unselfish work of these public benefactors.

As the great service rendered by these men becomes more fully realized, the credit due them will be freely given. Already monuments to their worth and wisdom are being made in nearly every township throughout the valley in the way of lateral ditches to supplement the work of the main State ditches secured to this valley through the persistent efforts of a few public-spirited men.

In the construction of these State ditches 1,862,865 cubic yards of earthwork were removed, many miles of which were taken from very wet swamp lands, where pitchforks, shovels and wheelbarrows were the only tools used by the hardy laborers.

The average price paid contractors for this work was 8.8 + cents per cubic yard, and the average cost, including all expenses, was 9.7 + cents per cubic yard.

There are in all twenty-two State ditches and extensions, very equally and fairly distributed among the eight counties of the valley. The largest of these ditches are 20 feet at the bottom, with a slope of 1½ to 1, and vary in depth from 3 to 10 feet. They could float a good-sized vessel in time of high water. One of these ditches at flood tide passes 320,000 gallons per minute. At this rate the water falling upon a square mile of surface during an ordinary all-day rain will be carried away by the ditch in less than an hour. It is estimated that more than 1,000,000 acres of land have been benefited by the construction of these State ditches. Hundreds of thousands of acres of these lands, including 130,000 acres which belonged to the State, have increased in value, by

reason of these State ditches, from five to twenty dollars per acre, and millions of dollars have been saved the farmers of the valley by these ditches, which, but for the ditches, would have been lost by floods. The estimated damages to the farmers of the valley in 1882 alone, from loss on crops by lack of drainage, was over $2,000,000. It is maintained by responsible farmers that one of those ditches in a single season saved more to the farmers, by preventing loss of crops by floods, than the total cost of the whole system of twenty-two State ditches. The farmers are enabled to put in their crops at least two weeks earlier by reason of these ditches, which means a saving of many thousands of dollars to them. The counties interested, seeing the benefit of drainage by the great success of the State ditches, are now completing the general system by putting in cross drainage ditches. Polk County alone has expended over $150,000 in this manner, and other counties are spending large sums of money in this work, and a few years will find the valley covered with a more comprehensive system of ditches than planned for by the original projectors.

With a seeding time one week to ten days earlier, thus insuring crops against early frosts and complete freedom from summer floods, the Red River Valley will soon take the place to which its rich soil and salubrious climate justly entitles it, as second to nothing within the boundaries of the State.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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ST. LOUIS WATER SUPPLY.

BY R. E. MCMATH, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, November 5, 1902.*]

STATEMENT OF THE PROBLEM TO BE CONSIDERED.

ST. LOUIS must improve its water supply in respect to its appearance and purity. It is desirable that the improvement be secured as soon as practicable, for muddy water, believed by many to be also impure, is not in harmony with the idea of a new St. Louis. The question is, How shall the city make the needed improvement?

Promise of speedy realization of better water is made by those who advocate filtration applied to and made a part of the present supply system. It is claimed that the installation of a filter plant to treat the entire supply can be provided for out of funds now in hand and current revenue.

The report of City Comptroller dated July 28, 1902, states:

Unappropriated balance, April 8, 1902	$1,541,431.85
Anticipated revenue 1902-3	1,750,000.00
Total available	$3,291,431.85
Deduct for expenses	722,456.98
Available for improvements 1902-3	$2,568,974.87

The cost of installing a filter plant was estimated by the Expert Commission (Appendix G) at $1,948,000.

*Manuscript received December 15, 1902.—Secretary, Ass'n of Eng. Socs.

An offer has been made by parties engaged in the business of installing filter plants to install a mechanical filtration plant to demonstrate its ability to clarify and purify water taken from the Mississippi River at Chain of Rocks.

We have therefore a result wanted, and an agency willing and ready to produce that result, and no difficulty in sight as to price or its payment. Why, then, do the authorities of the city hesitate to go ahead? The answer is an old one, but always new—Because of their unbelief.

The condition of unbelief may be undesirable, but it is a necessary stage of mind while a proposition is being considered, before acceptance or rejection.

The filter company making the offer is not moved by philanthropic considerations, nor by love for St. Louis. It is after business, and big business. Sentimental considerations should have no weight. The offer is a complication, and not an assistance, in settling the main question before the authorities, which, broadly stated, is, Does the City of St. Louis want filtered Mississippi water; that is, water taken from the Mississippi River at Chain of Rocks, pumped twice and filtered by any process involving the use of a coagulating chemical?

If the Mississippi at Chain of Rocks was the only possible source from which a water supply for the city could be obtained, the question as stated would still be the main question, but would extend only to the availability, cost and results of several methods of treating the water. Two modes involve the use of a coagulant; they are known as mechanical filtration and modified slow sand filtration, sometimes called "American" and "Modified English" systems. Two other modes of treatment do not use a coagulant; they are "Slow Sand" filtration (English) and "Plain Subsidence" for sufficient time to rid the water of suspended solids. If the question above stated is, after careful consideration, answered in the negative, then the next step is to consider the practicability and results of the methods not requiring the use of a coagulant.

But the Mississippi at Chain of Rocks is not the only possible source of supply; there are two others, the Missouri River and the headwaters of the Meramec River. The claims of the latter possible source to consideration are, principally, that the water would be delivered by gravity, and, therefore, save pumping, and would be so pure as to require no treatment to fit it for use.

The preceding two paragraphs set forth in plain terms the water question which is before the authorities and people of the City of St. Louis.

METHODS OF WATER TREATMENT—CONDITIONS OF SUCCESS.

For the removal of earthy matters from water, filtration is straining through a medium whose texture depends on the fineness of the particles to be removed. Early forms of filters were designed to secure a clear effluent only, but when the germ theory of disease was developed, and the conditions of bacterial life studied, it was found that the number of bacteria in water was largely reduced by filtration through sand. Later it was discovered that removal of bacteria by sand filters depended upon the formation of a gelatinous film on the sand. To this film the Germans gave the name "Schmutzdecke"; the English call it "Bacterial felt." Until the bacterial felt is formed so as to be a continuous surface film, penetrating to a very small distance below the surface and into the channels between the particles of sand, the effluent from a sand filter is unsatisfactory from a bacteriological standpoint. The film accumulates and resists the passage of water, and so, to renew the activity of the filter, the surface must be cleaned and the process repeated. Cleaning is done by removing the sand to moderate depth. The formation of the bacterial felt on the slow sand filter is due to the bacteria themselves producing a natural coagulum. Sand filtration is in consequence a comparatively slow process, requiring large area of filters.

Mechanical filtration aims to accomplish the same result rapidly by artificial production of the coagulum and frequent removals of the felt. This is accomplished by adding to the influent water a coagulant and removing the accumulated coagulum at short intervals by a reversed current of filtered water, which cleans and washes the sand. To mechanical filtration these three steps are necessary: first, coagulation; second, sedimentation, and third, filtration. In slow sand filtration the last two are essential; the first is not.

The action of a coagulant, usually sulphate of alumina, when introduced into a water containing carbonates of lime or magnesia, is to break up and enter into new chemical combinations, one of which is precipitated as alumina-hydroxide, which is of gelatinous appearance and claimed to be quite insoluble in water. This substance, falling through the water, entangles all suspended matter and bacteria and is deposited upon the surface of the sand. The layer so deposited replaces the naturally formed bacterial felt of the sand filter. Another claimed action of the precipitated hydroxide is to unite with the dissolved coloring matters of tinged or stained waters, removing them and producing a clear and sparkling product, which cannot be attained by slow sand filtration.

The use of a coagulant is therefore essential to mechanical filtration. It is just as essential that the quantity of coagulant be duly proportioned to the work it has to do.

A clear water containing the necessary carbonates must receive a dose proportionate to the work to be done. If the dose be too small, the action is incomplete; if too large, undecomposed alum will pass into the effluent. If the water be turbid, the dose must vary with the turbidity, and kind of turbidity; if the water is colored the dose must increase on that account. This suggests that proportioning and administering the dose is a very delicate matter. An expert chemist and bacteriologist must be at hand to fix the proportion; an expert must be employed to make the application.

Considering that Mississippi water at St. Louis comes from numerous tributaries draining a vast area, 700,000 square miles, considerable variation in the quality of the water and its chemical constituents must occur. The flood and low stage periods of the tributaries are irregular, and the characteristics of the water will depend upon the tributary whose flood waters may be passing at any time, and may change in a few hours from those of one tributary to another.

The task of adjusting the dose to the varying conditions is admitted to be vastly more difficult at St. Louis than at any other locality where coagulation and filtration are used or have been proposed. Mr. Allen Hazen, of the St. Louis Expert Commission, in his minority report to Mayor Wells, recognizes the difficulty, saying, page 76 of report: "It is true that the water at St. Louis is a difficult one to treat; that more thorough methods must be used than are necessary elsewhere."

Slow sand filtration, as practiced in Europe and some American cities, has high bacterial efficiency, and is credited with a material decrease in number of deaths from typhoid fever wherever it is used. Its dependence upon "bacterial felt" has already been stated. The rate of filtration may be taken as 3,000,000 gallons daily per acre; hence the area of filter required at St. Louis for 100,000,000 supply would be somewhere near 40 acres, allowing for the need of scraping and renewing the surface and the formation of the bacterial felt. It is considered that the amount of suspended solids in influent water must not exceed 125 parts in a million. To attain this limiting turbidity a second sedimentation would be required, since the present sedimentation does not reduce the suspended solids much below 300 parts in a million, as an average. It is appropriate to say in this connection, though the

remark applies to all methods of water treatment, that average results are of little consequence. From the hygienic point of view, the worst conditions are the important ones, though they continue but a few days at a time.

To meet the condition of excessive turbidity continuing but a few days at a time, "Modified Slow Sand" filtration has been suggested for Cincinnati and recommended for Washington, D. C. The modification consists in the use of a coagulant, during periods of excessive turbidity, to reduce the suspended solids within the limit of 125 parts per million in the water when it passes to the sand filtration beds.

"Plain Subsidence" is a method with which St. Louis has had practical experience, but it has not been extended beyond subsidence for about 60 hours. How long subsidence would be necessary to obtain a fairly satisfactory water, without other treatment, is not known. But we do know that water standing, in considerable bodies, at rest, does become clear and pure by natural process of sedimentation. Of this fact lakes are the conclusive evidence.

In several instances filtering galleries have been constructed under, or alongside of, bodies of turbid water to receive water percolating through the intervening material. For the sake of a name this method may be called "Induced natural filtration." It has been suggested that an opportunity for this method might be developed on the Missouri River. Hence it is necessary to mention the method in a discussion intended to be fair to all.

CONTROLLING CONDITIONS OF WATER SUPPLY FOR ST. LOUIS.

Mississippi River water at St. Louis is always turbid. During parts of every year it is very heavily burdened with suspended solids, sand and clay. The sand quickly subsides when the water is at rest, but the very finely divided clay matter settles very slowly. In addition to the burden of earthy matter, the water contains much organic matter from land drainage and the sewage of many cities. By the census of 1900 the urban population, cities of 4,000 inhabitants and over, was reported. Cities on watershed of Upper Mississippi, its tributaries and Chicago sewage canal, 3,252,481; cities in Missouri watershed, 1,090,832; total urban population above St. Louis, 4,343,313. This urban population is doubtless increasing more than 100,000 each year. The probable sewage pollution is already considerable, and will surely increase. Rural population and animals add much to the prospect of pollution. Except the products of decomposed sewage, the matter has nothing

in solution which is detrimental to health. The turbidity of the water makes it repulsive in appearance and unfits it for many uses; hence it must be clarified. The suspicion of pollution justifies a demand that it be purified, also.

To obtain, clarify and purify water taken from the Mississippi at Chain of Rocks the following steps are necessary to the mechanical or modified English methods:

1. Pumping from river to sedimentation basins.
2. Preliminary sedimentation.
3. Introduction of coagulant.
4. Second sedimentation.
5. Filtration.
6. Pumping for distribution.

If the city would be content with a slightly clouded water and a diminished purity, it is possible to obtain a greatly improved water by plain subsidence.

This method would dispense with the third step and substitute a third and extended subsidence in receiving reservoir for the fifth step.

St. Louis is a manufacturing city, and expects to become much more so. The uses of water in connection with industries are of much importance, and no treatment of the water which will materially injure it for such uses is admissible. The success or failure of a locality as a manufacturing center often depends on what may seem small questions which affect the cost of products.

Observations of water from the Chain of Rocks intake were made January to December, 1900, and January to June, 1901, as to amount of suspended solids. The monthly means varied in 1900 from a maximum of 2,483 parts in a million in July to a minimum of 195 in December. Average for 11 months, 1,209 parts. In 1900 the monthly means varied from maximum 2,705 in June to 207 in February. Average for 6 months, 1,015 parts. Average for 17 months, 1,140 parts. Since the season of 1901 was without usual spring floods, 1,200 parts per million may be assumed to approximate the normal average.

The limit of suspended solids in water to be filtered by slow sand process is taken at 125 parts per million. In 17 months of 1900-01 the quantity exceeded this limit 449 times out of 462, or 97½ per cent. of the observations. Observations of water taken near Illinois shore, Chain of Rocks, gave maximum monthly mean, June, 1901, 2,073; minimum, December, 1900, 73. Average 17 months, 522 parts. The average on the Illinois side is, therefore, less than one-half that at the intake. This is due to the fact that

the moderately turbid water of the Upper Mississippi has not been thoroughly mixed with the muddy Missouri water.

USES MADE OF WATER.

The quantity of water required by a city is usually expressed as so many gallons per capita daily. In estimating future wants, the Expert Commission assumed that the consumption might be kept at 110 gallons per capita daily, equal to 40,150 gallons for a year. This assumption of a uniform per capita for future years is not warranted by experience. Most of the consumption of water is, in fact, independent of the number of people.

By an analysis of the table, showing daily consumption of water from April 1, 1900, to April 1, 1901, given in the Water Commissioners' report for that year, page 23, something of a clue may be found for an estimate of some uses.

The sprinkling of streets began March 15th and ended November 30th. The use of water on lawns and grounds is mostly made between these dates. From the table we find that the total water consumption between March 15, 1901, and November 30th was 17,025.6 million gallons, a daily average of 65.48 millions. During the non-sprinkling period the total consumption was 5,968.0 millions, giving a daily average of 56.84 millions. The difference, $65.48 - 56.84 = 8.64$ millions, may be taken as the daily average of water used for sprinkling and other uses which depend on the season.

$8.64 \times 260 = 2{,}246.4$ millions, which is 9.77 per cent. of the total quantity for the year, 22,993,668,600 gallons.

If the consumption on Sundays and Christmas be summed, 2,948.1 millions, it gives an average Sunday consumption of 54,594 millions, and the weekday consumption, 20,045.4 millions, gives 64.454 millions as the average weekday consumption. The difference, $64.454 - 54.594 = 9.86$ millions, is the average decrease due to cessation of use on Sundays for industrial purposes. If it be assumed that this is about one-half of the normal weekday use, we obtain: $9.86 \times 2 \times 311 = 6{,}132.92$ millions used on weekdays; $9.86 \times 1 \times 54 = 532.44$ millions used on Sundays, making total, 6,665.36, which is 28.99 per cent. of the yearly consumption, as an approximation to the proportionate quantity used for industrial purposes.

The use for sprinkling and industries obviously has no direct relation to the population.

To arrive approximately at the use which does depend upon the number of people, it is well to make a liberal allowance, such as:

Drinking water, 1 gallon daily per capita; preparation of food, 2 gallons daily per capita; kitchen use, 5 gallons daily per capita; a total of 8 gallons daily per capita.

The population in 1900 was 575,238.

575,200 × 365 × 8 = 1,679,584,000, which is 7.30 per cent. of the total consumption for the year.

The use of water for baths and laundry purposes is also proportioned to population. If 25 gallons daily be allowed for these purposes, 575,200 × 365 × 25 = 5,248,700 = 22.83 per cent. of total consumption.

Making an arbitrary division of loss and waste, slip of pumps, 4 per cent.; evaporation, leakage of conduit mains and distribution, 12.11 per cent., and defective plumbing and wilful or careless waste, 15 per cent., we may make a schedule:

Slip of pumps	4.00%	Taken as	4%
Leakage of city mains, etc.	12.11%	" "	12%
Leakage private pipes and waste	15.00%	" "	15%
Sprinkling or season use	9.77%	" "	10%
Bath and laundry use	22.83%	" "	23%
Industrial use	28.99%	" "	29%
Drinking and house use	7.30%	" "	7%
	100.00%		100%

PROBABLE NEEDS OF THE CITY.

The data available for a forecast of the probable needs of the city for its future water supply are meager. The present supply system is practically one of direct pumping into the distribution, for the storage reservoir at Compton Hill, capacity 60,000,000, can only assist to tide over a deficiency for a few days.

The times of greatest consumption occur when the summer heat and winter cold are excessive, and the increased consumption at such times is largely waste. Until waste is brought under control, the city must provide against these extremes. Hence the maximum consumption represents the need for water which must be met, and a month is the longest period which may be averaged to obtain a measure of the need.

If the estimate of "Average daily consumption" and of "Average daily consumption for month of maximum consumption," given on page 32 of Water Commissioners' report, 1900-01, are extended, following the apparent basis of estimate we get the first four columns of the following table; since the result is evidently too great, a more probable estimate is made in columns 5 to 8:

	By extension of official figures.			By Population and per capita use increasing 2000 gallons every three years.			
Year.	Average daily consumption. Millions.	Deduced daily use per capita. Gallons.	Daily average consumption in maximum month. Million gallons.	Estimated Population.	Daily use per capita. Gallons.	Average daily consumption. Million gallons.	Average daily consumption in maximum month. Million gallons.
1.	2.	3.	4.	5.	6.	7.	8.
1901	69.00	117.2	82.00	588,800	110.6	65.16	71.110
1904	82.00	129.9	97.00	631,200	112.7	71.11	77.610
1907	97.00	143.3	114.00	676,800	114.7	77.61	84.650
1910	114.00	157.1	133.00	725,600	116.6	84.65	91.940
1913	133.00	171.5	154.00	775,700	118.7	91.94	100.050
1916	154 00	185.7	177.00	829,200	120.7	100.05	108.740
1919	177.00	199.7	202.00	886,500	122.6	108.74	117.910
1922	202.00	213.6	229.00	945,800	124.7	117.91	127.670
1925	229.00	227.2	258.00	1008,000	126.7	127.67	138.240
1928	258.00	240.2	289.00	1074,000	128.6	138.24	149.460
1931	289.00	252.6	322.00	1144,000	130.6	149.46	161.220
1934	322.00	265.0	357.00	1215,200	132.7	161.22	178.480

From these estimates it would appear that St. Louis must soon take steps to extend its water works, as well as improve the quality of the water. It is stated in Appendix "H" of Expert Commission report, page 161, "that in December, 1901, the city was in danger of shortage of water," when high-service pumps of nominal daily capacity of 139,000,000 gallons were in use. The figures above indicate that there will be continued shortage by 1909, and shortage in maximum month in 1907.

The present reported pumping capacity, low service, at Chain of Rocks is believed to be reliable, but for the maximum month's supply we must allow that one engine will be out of service, hence the practical limit will be 130,000,000 for the present station. The three old-style engines at Bissells Point, H. S. No. 2, cannot be rated higher than 16,000,000 each; together, 48,000,000 daily. The three new-type engines under construction may be taken at 60,000,000. But for actual work one of the six engines at Bissells Point must be in reserve, hence the working capacity of the station is not more than 48,000,000 + 60,000,000 — 20,000,000 = 88,-000,000 daily.

At the Baden High Service Station there are, or will soon be, two 10,000,000 pumps and four 15,000,000, a total capacity of 80,-000,000. Allowing one engine in reserve, the working capacity is 65,000,000 gallons daily. The total present working capacity of both stations is, therefore, 88,000,000 + 65,000,000 = 153,000,000.

The entire water supply is carried from Chain of Rocks to

Baden by a conduit having an easy capacity of 110,000,000, which may be forced to 150,000,000. The smaller conduit from Baden to Bissells Point has a safe capacity of 65,000,000, which may be increased to the working capacity of the Bissells Point pumps.

From the data we may conclude that the present works have a capacity for regular work of 110,000,000 gallons per day, and may, to meet emergencies, be operated at 15,000,000 gallons.

From data given on page 43 of Water Commissioners' report for 1901-02 and estimates of population between census years the following table is obtained:

Year.	Estimated Population.	Miles of water mains.	Persons per mile of main.	Number of taps in service.	Persons per tap.	Water consumed per capita in year.	Water consumed daily per capita gallons.	Water consumed per tap, gallons in year.	Average number of taps per mile of main.
1880									
1881	350,518	212	1,653	20,204	17.35	28,120	77.0	488,000	95.310
1882	359,450	225	1,598	21,745	16.53	27,320	74.9	463,100	96 60
1883	368,620	234	1.575	23,648	15.58	28,200	77.3	439,700	101 00
1884	378,020	238	1,585	25,321	14.93	25,240	69.1	376,900	106.40
1885	387,660	257	1,508	27,457	14.12	24,280	66.5	342,800	106.80
1886	397,540	279	1,425	29,884	13.30	24,690	67.6	328,500	107.10
1887	407,680	295	1,382	31,794	12.82	26,680	73.1	342,100	107.80
1888	418,070	314	1,231	34,022	12.29	27,500	75.4	338,600	108.30
1889	428,730	336	1,276	36,082	11.88	26,760	73.3	318,200	107.40
1890	439,670	354	1,242	38,183	11.52	26,980	73.9	310,700	107.90
1891	451,770	373	1,211	41,331	10.93	29,100	79.7	318,000	110.80
1892	462,890	393	1,178	44,382	10.43	31,220	85.5	325,000	112.90
1893	474,180	410	1,156	47,445	10.00	34,060	93.3	340,200	115.50
1894	485,790	447	1,087	50,540	9.61	35,750	97.9	343,600	113.00
1895	497,700	462	1,077	53,354	9.33	40,240	110.3	375,400	115.50
1896	509,900	493	1,034	56,865	8.97	38,320	105.0	343,700	115.30
1897	522,400	532	982	59,423	8.79	35,710	97.8	313,100	111.70
1898	535,200	555	964	61,839	8.65	38,050	104.3	329,300	111.40
1899	548,300	581	944	63,851	8.59	37,930	103.9	325,800	109 90
1900	561,700	616	912	65,688	8.55	39,370	107.9	336,600	107.00
1901	575,200	638	902	67,243	8.55	39,970	109.5	341,900	105.40
1902	588,800	669	880	69,483	8.47	41,670	114.2	352,900	103.90

The principal lesson to be drawn from this table is that the per capita use of water is steadily increasing, and that it will in all probability continue to increase. The persons per tap seem to be approaching a limit.

The increase per capita from 1890 to 1900 has as tangible reasons: (1) A greater proportion of the population was served with water; (2) wells and cisterns were disused; (3) systematic street sprinkling introduced after 1880 was not complete in 1890; (4) the movement of the well-circumstanced people to new parts of the city greatly increased lawn sprinkling; (5) progressive

change of habits as to bath and laundry use of water, people being better housed and having more conveniences; (6) large increase of use for industrial purposes.

The use of water for legitimate purposes will be likely to increase in more rapid ratio than losses by leakage and waste will decrease; therefore, the per capita of water consumed will continue to increase, but at a much less rapid rate than from 1890 to 1900. The writer assumes that by steady increase it will reach 150 gallons per day by 1960.

The normal increase in population is logically at a compounding rate, which rate may be expected to diminish slowly. If the census population in 1880 is taken to have had a yearly rate of increase of 2.55 per cent., computation would make an expected population of 450,676 in 1890. The census of that year found 451,770. Again, computing from the 1890 census figure, at yearly rate of 2.45 per cent., the computation gives 575,482 for 1900. It may be inferred from the data that the yearly rate diminished by 0.10 per cent. in each successive decade. In this way the population, column No. 3 in the table following, has been computed.

GROWTH OF WATER CONSUMPTION AND REVENUE.

Year.	Yearly rate of increase for next decade.	Estimated Population.	Yearly per capita of water at 110 gallons daily per person.	Estimated total years consumption. Millions. Col. 3 x Col. 4.	Average daily consumption in Millions. Col. 5÷365.	Yearly per capita if daily use increases from 110 to 150 gal.	Estimated total year consumption. Millions. Col. 3 x Col. 7.	Average daily consumption. Millions. Col. 8÷365.	Water revenue computed at $70 per million gallons. Col. 8 x $70.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1900	2.35%	575,238	40,000	23.000	63.00	40,000	23.000	63.00	$1,610,000
1910	2.25%	725,615	40,150	30.113	82.50	42,460	30.810	84.70	2,156,700
1920	2.15%	906,420	40,150	37.616	103.10	45,920	40.788	111.70	2,855,160
1930	2.05%	1121,160	40,150	46.528	126.50	47,370	53.154	145.60	3,720,780
1935	....	1240,900	40,150	51.497	141.10	48,600	60.396	165.40	4,227,720
1940	1.95%	1373,400	40,150	56.996	156.20	49,850	68.532	187.70	4,797,240
1950	1.85%	1663,900	40,150	69.052	189.00	52,290	87.022	238.40	6,091,540
1960	....	1998,700	40,150	82.946	225.20	54,750	109 396	299.70	7,657,720

To a consideration of the city's future water supply it is important to have an approximate idea of the direction in which the city will expand, and what will be the probable limits of its expansion.

Opportunity for proper drainage will be the chief factor in determining direction and limits. Maline Creek and its branches will nearly define the northern limits, and the Des Peres and its branches will practically define the southern and, in a great measure, the western limits of urban and semi-urban population. If lines

are drawn directly west from Chain of Rocks and mouth of Des Peres, they will include nearly the entire territory whose sewering would be reasonably easy.

The Chain of Rocks is at the northeast corner of the city now, and is likely always to be so. The Chain of Rocks will, therefore, not be a good location from which to distribute water for the greater St. Louis of the future, and this fact is a strong argument against extending the works at Chain of Rocks more than to develop the present capacity of conduits and pumping engines.

Under the State Constitution the city has had no financial resources applicable to water-works improvement, except the surplus of water revenue and its accumulation after paying all maintenance, operation and administration expenses.

This condition has been materially changed by amendments adopted at the late election. Water revenue must now provide for the interest and principal of old bonds to the amount of $5,808,000, now bearing 4 per cent. interest. As these bonds fall due they may be renewed for a term of 20 years. The city is also authorized to issue new bonds for such an amount as the surplus water revenue is able to pay interest and provide for payment of principal within 20 years after date of issue.

The amount of new bonds which might be issued to pay for new work would be from $20,000,000 to $25,000,000.

Since the amendments make the water revenue bear a burden heretofore borne by another fund, raised by direct tax on property, and since municipal revenue will be largely increased by the amendments, it will be just and proper to relieve the water works from furnishing free water for municipal purposes; that is to say, the city should treat the water works as a business conducted under municipal ownership. This course would add considerably to the estimated resources of the water fund.

MERITS AND DEMERITS OF THE SEVERAL METHODS OF TREATING WATER.

Sand filtration has been in use for a long time and on a large scale in Europe and America. It is, in fact, nature's process of clearing water applied through filters of man's construction and arrangement. The limitations of man's work do not allow exact duplications of nature's process, such as unlimited time and great area and depth of material.

The conditions of successful slow sand filtration are: That the amount of suspended solids must not exceed 125 parts in

a million; the water must contain enough bacteria to form a bacterial felt over the entire surface of the filter in a reasonable time; the bacterial felt by accumulation lessens the rate of filtration and must be removed and a new felt formed; the working capacity is not more than 3,000,000 gallons per acre daily.

Mississippi water at St. Louis, after 60 hours of sedimentation, is usually much too turbid for slow sand filtration; therefore no one suggests or advocates this method at St. Louis, and its further consideration here is unnecessary.

In "modified slow sand filtration" the modification consists of the use of a coagulant and sedimentation to remove excess of turbidity and so prepare the water for filtration. After such preparation the conditions of success are the same as for slow sand filtration.

The method was suggested by Mr. George W. Fuller for Cincinnati in his report to the Board of Trustees, January 31, 1899, and has been recommended, but not yet adopted, for Washington, D. C., after much discussion of the relative merits of this method and of mechanical filtration. The evidence of experiments is against its practicability when applied to turbid waters, such as the Ohio, Potomac and Mississippi Rivers.

Mr. Fuller's suggestion at Cincinnati followed an elaborate experimental study of Ohio River water. After an experimental study of Potomac water, Colonel Miller, U. S. Engineer, recommended the mechanical filtration system. Opposition sprung up, and the Committee on District of Columbia of U. S. Senate invited a number of men having reputation as experts on filtration to appear before the Committee to testify. After the hearing the Committee employed Messrs. Rudolph Hering, George W. Fuller and Allen Hazen to advise the Committee as to a conclusion. The body of testimony is valuable as expressing the latest views of practical and theoretical men of established reputation.

The water question at Washington was as to the best method of treating water taken from the Potomac River at Great Falls, passed through a receiving reservoir and conduit to a distributing reservoir. The proposed filters were to be located between the distributing reservoir and the city, hence the water would have two periods of subsidence before entering the filters. Observations showed that at Great Falls the water was turbid 53.8 per cent. of the time, after passing the receiving reservoir about 45 per cent., and after passing distributing reservoir, 35 per cent.

The standard of turbidity was that a copper ball 1 inch in diameter should be visible through 22 inches of water. If visible,

"no objection is made to the water on the score of turbidity." At Cincinnati excessive turbidity was found 36 per cent. of the time in river water, but the standard was 125 parts of sediment in 1,000,000. At the intake of St. Louis water works the standard of 125 to 1,000,000 was exceeded 97.6 per cent. of the time in 1900 and 97.2 per cent. from January to June, 1901.

Water from outlet chamber of settling basins showed excess of turbidity in 34.3 per cent. of the observations. Apparently the subsided water of the St. Louis water works is slightly less turbid than the natural water of the Ohio at Cincinnati. Assuming that water rated as "turbid" at Washington, 8 to 14 inches visibility, approximated the ratio 125 to 1,000,000 then excess of turbidity after one sedimentation existed 29 per cent. of the time. The three proportions of time, Cincinnati, 36 per cent.; Washington, 29 per cent., and St. Louis, 34 per cent., look as if the conditions were similar and the treatment that would be good for one would answer for all; but there is this important difference; The excess period was continuous at St. Louis from April 10th to May 27th in the exceptionally dry spring of 1901, while at the other localities it continued for a few days at a time. In normal years, such as 1900 may be taken to have been, the excess after subsidence at St. Louis would have been continuous from March to November, 9 months. This means that if the modified sand filtration system were adopted for St. Louis, to follow sedimentation, as now practiced, the use of coagulating chemical would be necessary three-fourths of the year, instead of occasionally for a few days, as at Washington.

The sand filtration which in this system follows coagulation depends on the formation of the bacterial felt by the bacteria themselves, as has been said. It is a known fact that Mississippi water loses a large part of its bacteria by natural subsidence; many more will be entagled in the coagulum resulting from the use of a chemical and will be deposited in the settling basins. The question arises whether there will be enough bacteria in the water, after coagulation and subsidence, to form the necessary gelatinous film on the sand filters.

Experiment and experience has caused some doubt whether Mississippi water, after natural subsidence, contains enough bacteria to insure practical success of sand filtration. This doubt is strengthened by evidence.

Mr. George W. Fuller, in his Cincinnati report, page 142, said: "One of the most characteristic features of the English filters operated at Cincinnati was the comparative absence, with a

few possible exceptions at times, of very low or fairly clear water in the river, of such gelatinous surface coating (Schmutzdecke) as is almost universally associated with filters of this type."

In the Senate Committee investigation Mr. Fuller was asked (page 48): "*Q.* In the study of our Potomac water, so far as you have examined this report, is there anything to indicate that such organic matter was absent? *A.* I gather that it was absent, but I cannot state it specifically. *Q.* You state further that the slow sand filters failed there because of 'the imperfect formation of a gelatinous surface coating upon the top of the sand layer.' Is there any indication in the report of Colonel Miller of 'an imperfect formation of a gelatinous surface coating on top of the sand layer?' *A.* I gathered the impression that there was something abnormal at Washington on that general line."

Mr. Robert Spurr Weston, who was in charge of the Washington experiments, said (page 126): "This biologic action, so essential to the operation of sand filters, does not occur at Washington, since nearly all of the organic film-forming material is absorbed by the particles of silt during the turbid seasons, leaving none to form a film on the sand grains."

The evidence establishes that a water, once turbid, when cleared of turbidity by plain sedimentation, or coagulation and sedimentation, is biologically too pure for successful subsequent slow sand filtration. By obvious inference, this biological purity greatly reduces the need for further treatment by any process.

The presence in the water of finely-divided clay causes another serious practical difficulty in the way of sand filtration. The very fine particles penetrate the body of sand and eventually destroy its efficiency by making it impervious, or they are washed through.

Although modified slow sand filtration was recommended for Washington, the force of the precedent disappears when the vastly greater turbidity due to fine clay in Mississippi water at St. Louis is taken into account.

The great and nearly continuous turbidity of Mississippi water would require the nearly continuous use of coagulant in large quantities, with its attendant expense.

Sand filters would fail for want of the necessary bacterial felt.

Sand filters would be clogged by the very finely divided clay lodging in the body of the filter.

These three substantial reasons are enough to warrant the rejection of modified slow sand filtration for St. Louis, without taking into consideration other objections which might be raised.

These objections will of necessity be considered when discussing the rival method of mechanical filtration.

The treatment of turbid and other undesirable water with chemicals is doubtless as old as civilization. The Hindoos have practiced it from time immemorial, and the Egyptians no doubt did the same. Sulphate of alumina or alum has been repeatedly used to purify water supplies in Holland at "Groningen, Gonda, Schiedam, Loewarden, Delft, Alkmaar and Vlaardingen."

The use of a chemical agent as coagulant is essential to mechanical filtration whether the water be clear or turbid, else the process would be no more than rapid straining of water, too rapid to do much good. With a coagulant it is claimed that suspended solids are taken out, bacteria almost entirely caught, but not killed, and color removed. The principal results come from the chemical action; the mechanical parts regulate the introduction of chemical, the influx and efflux of water and the cleaning of the filter.

The appliances used for these purposes are many and ingenious. Of course, the appliances are patentable and the patents number several hundred, most of which have passed into the hands of a combination which has capital and the command of skill, legal and business ability. Very naturally, the combination promotes its business by setting forth the merits of the system in the strongest light; the demerits, if any exist, must be found, as they best may, by the cities or citizens with whom the combination tries to do business.

Several years ago the Board of Public Improvements of St. Louis took the position that a series of experimental studies should be made by and at the city to develop the local conditions. It did so because the conditions of successful filtration of Mississippi water on the large scale required for the city are not known, and may not safely be assumed to be the same or even like those suited to Ohio water at Pittsburg, Cincinnati or Louisville, Potomac water at Washington or any other water whose peculiarities have been studied experimentally or practically.

The Municipal Assembly repeatedly refused to authorize the experimental studies, and ignorance as to the peculiar qualities of St. Louis water continues.

Although it has been confidently asserted that mechanical filtration has passed out of its experimental stage and is now on sure ground, there seems to be much uncertainty in the minds of experts.

Mr. Allen Hazen, of the St. Louis Expert Commission, in his minority report said (page 76): "I believe that the construction and operation of the proposed filter plant involves no difficulties which cannot be successfully met." The somewhat slender foundation for his belief is disclosed in what he said before the Senate Committee (page 23): "It is possible to operate them to give very bad results, or it is possible, by taking great care, and particularly by using large amounts of chemicals, to get very high efficiencies."

"*Q.* What advantage has the mechanical filter to recommend its use in preference to the sand filter? *A.* The mechanical filter is always used in connection with a coagulant, and the coagulant is necessary for the treatment of extremely turbid water. *Q.* Is Necessary? *A.* Yes, is necessary, so that when a water is so turbid that it must be coagulated, it is better, or, at least, cheaper, to filter it with the mechanical filters. *Q.* That opens up two questions, better and cheaper. *A.* I think it has usually been decided upon because it is cheaper. *Q.* Then you would have no hesitation in saying that a mechanical filter properly constructed will give satisfactory results from the standpoint of bacterial efficiency? *A.* A mechanical filter can be operated to give a very high bacterial efficiency. *Q.* Well, have they been so operated? *A.* In plants actually built? *Q.* Yes. *A.* I do not think so; at least, not very often. I have tested some mechanical filter plants and operated them—experimental mechanical filter plants—and plants on a considerable scale, and while it is possible to obtain very good efficiencies, there are a good many things in connection with mechanical filters to cause low degrees in the efficiency. It seems to me that there are greater possibilities of accidents of this kind happening with mechanical filters than with sand filters, where the operations take place more slowly and, it seems to me, can be more perfectly controlled."

Mr. George W. Fuller gave support to Mr. Hazen as minority of St. Louis Expert Commission and his contributions were printed (pages 80-86). He minimized the difficulties (page 82). "So far as filtration proper is concerned at St. Louis, therefore, the project involves no problems materially different from or more difficult than a number of others which have been considered in great detail, and for which works are now being constructed." It is evident that his confidence was not based on realized results at other cities, but on expected or hoped-for results of incomplete works. The context shows that Mr. Fuller had in mind works

for "the treatment of fairly clear surface waters, which in the eastern part of this country have been successfully purified by filtration when the conditions of construction and operation are favorable." (Page 82.) If Mr. Fuller had realized results with fairly clear eastern water instead of hoped-for as a ground of confidence, he would still have had no ground for an unqualified assertion as to St. Louis water. Speaking of the specific character of Potomac water, he said to Senate Committee (page 41): "I consider this to be a fundamental essential to a satisfactory solution of your problem. That is to say, it is not the question of a system of filtration that has got to be considered by itself, but you have to consider the subject with reference to the character of the Potomac water as it leaves the Washington reservoirs." He then followed with an elaborate statement as to difference between eastern waters, coming from glacial drift formations, and southern waters, containing much clay, the Potomac being in a middle class. St. Louis water belongs in the clay-bearing class. Hence eastern precedents, if they were real, would be of no value as to St. Louis elemental essentials.

Messrs. Rudolph Hering, George W. Fuller and Allen Hazen were employed to advise the Senate Committee. In their report (page XIV of Senate Report No. 2,380) they showed a favorable leaning toward mechanical filtration, saying: "As to the relative merits of the two systems of purification studied by Colonel Miller, namely, the treatment of plain subsided water by sand and mechanical filtration, his conclusion is correct, namely, that the latter system would be the more efficient and the more judicious one for the City of Washington to adopt." On page XV they say: "Practical experience with sand filters is more extensive and more favorable than with mechanical filters. Our knowledge of what they will do rests not alone upon experimental investigations, but upon actual use for many years by some of the largest cities of the world. The force of this statement is somewhat reduced, however, by the fact that the raw water at Washington is more turbid than the raw water at the places where sand filters have been generally used."

"Our knowledge as to the results that can be obtained by mechanical filters rests more upon experimental evidence than upon results obtained in practice."

"After a full consideration of the various aspects of the problem, we are of the opinion that the long and favorable experience

with sand filters, particularly in the light of the effect which they had upon the health of the communities using them, should be given greater weight than the present evidence that American filters are able to give substantially equal hygienic efficiency. In view of the fact that there is no available evidence of decided advantage to be gained by adopting the newer method, we prefer in this case to adhere to the one supported by long precedent."

Their conclusion (page XVI) was: "In consideration of the full evidence, we recommend the construction of a complete system of slow or sand filters, with such auxiliary works as may be necessary for preliminary sedimentation, and the use of a coagulant for a part of the time. There is no reason to believe that the use of this coagulant will in any degree affect the wholesomeness of the water."

Evidently the opinion of these experts, February 8, 1901, was that mechanical filtration on a large scale was too much of an experiment to justify its adoption at Washington. Nevertheless, only eleven months later two of them recommended its adoption for St. Louis, where it is admitted the much greater and persistent turbidity of the water greatly increases the difficulties to be overcome, and where the presence of much clay, very finely divided, adds a difficulty which is scarcely recognized at Washington.

From the evidence available at the present time the conclusion is unavoidable that mechanical filtration is too uncertain as to practical results, and the risk of operation on the extensive scale required too great, to justify its adoption for St. Louis.

Mechanical filtration is given a prominent place in this discussion because it has been distinctly proposed, and its adoption by St. Louis is being urged. In fact, the people of St. Louis have heard but little concerning other possible methods of treating water. So far as other methods involve the use of chemicals, they belong to the same class and are open to the same objections. The action of the chemical is one of the chief elements of uncertainty in mechanical filtration, and equally so in modified sand filtration. The Washington case did much to bring to light the weak points of the one. The recommendation of the other, so far from being a precedent to be followed by St. Louis, should put our city on its guard. Washington and St. Louis are in strong contrast. Washington, if it has any alternative to the use of

Potomac water, does not know it. St. Louis has alternatives. Washington is not a manufacturing city. St. Louis is.

It is the ambition of filtration interests to have their system adopted by a large city as it has been by small. Small cities have no alternative; their supplies come from small streams or lakes and need purification. Their financial resources are limited; that is, the power to borrow, by constitutional provisions, usually to 5 per cent. of assessed valuations, and the total valuation, even if the city has no prior debt, would be too small to bear the greater first cost of constructing sand filters; gravity supply of water in most cases is out of the question, or the cost prohibitive, and the quantity of water is too small for effective clarification and purification by subsidence or any other means than filtration. To these conditions we may add that mechanical filtration, being in fact property, through control of numerous patents, has been actively and ably promoted, as well as advocated, by the interested parties. The small cities could do no better, and may have done wisely in accepting mechanical filtration.

How is it with St. Louis? True, the city's present supply greatly needs improvement. But the needed improvement can be secured in more than one way.

The possibility of securing a water practically clear and satisfactorily pure by plain subsidence, and thereby avoid the cost of filtration and the grave objections to use of a chemical coagulant, has not been exhaustively studied. Moreover, it is almost certain that St. Louis could obtain an ample supply of pure water, delivered by gravity, at a cost within the city's financial ability, and so save the great and continuing expense of pumping and treatment.

The chemical treatment of water is objectionable, first, on account of its continuing cost. It is customary to speak of coagulant as being used in amounts of from ½ to 10 grains per gallon. Grains and gallons are small units to measure large quantities. The yearly consumption in 1906 will be at least 26,800 million gallons. Allowing an average of 4 grains to the gallon and $25 a ton for alum gives 7,557 tons at a cost of $188,925. Adding to this cost of chemical $6,075 for other expenses gives $195,000, which is equal to the interest on $6,000,000 at 3¼ per cent.

A second objection to chemical treatment is that it increases the hardness of the water and compels the use of greater quantities of soap. It has been estimated that a saving of 100,000 yearly would result from adopting soft water for a supply of 80,000,000

gallons daily. It increases the corrosive action on boilers and pipes, which shortens the useful life of steam and other plants. It adds to encrusting qualities, which results in diminished efficiency of fuel for heating and industrial purposes.

Making low allowances, we may roughly estimate: Extra soap, $\frac{1}{2}$ cent per week per capita, $661{,}000 \times .26 = \$171{,}860$; extra depreciation of steam plants, $\$5{,}000{,}000 \times .015 = \$75{,}000$; loss of evaporating efficiency of fuel, 7,000,000 bus. $\times .0075 = \$52{,}500$; total, $299,360.

This sum equals the interest at $3\frac{1}{4}$ per cent. on $9,211,000. It thus appears that, acting in the interest of the people, the city would be warranted in expending $\$6{,}000{,}000 + \$9{,}211{,}000 = \$15{,}211{,}000$ to avoid the cost and money-measured consequences of chemical treatment.

A third objection to chemical treatment, joining money and supposed sanitary considerations, is that, allowing the claim that the water is made more wholesome by coagulation and filtration, the proportion of the total supply which is in any way made better for the uses to which it is put is small. It has been shown that the proportion is 7 per cent. benefited, 52 per cent. injured, 10 per cent. neutral and 31 per cent. wasted. Wherefore, using figures given above, it would cost the city $\frac{195{,}000}{26{,}450{,}000{,}000} \times .07 = \$105.32$, and the citizens $\frac{299{,}360}{26{,}450{,}000{,}000} \times .07 = \$161.14$ per million gallons for each million which anyone can claim to be the better for filtration. If it be assumed that there are 100,000 families in the city who would use filtered water for drinking and food preparation, then $\frac{195{,}000 + 299{,}360}{100{,}000} = \$4.94$ per family, which would buy a good filter, new each year. Therefore, it would be good policy for the city to furnish each family with a modest filter, rather than adopt chemical treatment for the entire supply. It must be noted that this argument assumes that a clear water can be had without chemical treatment.

A fourth objection to chemical treatment is that the chemical used, alumina sulphate, has undesirable effects on the human system, and is, therefore, to be avoided.

In regard to the effect of alumina sulphate and the derivative, alumina hydrate or hydroxide, we have, on the one hand, the assertion of filtration advocates that alum used in properly proportioned doses unites with carbonates of lime and magnesia, and that alumina

hydrate is the new form taken by the released alumina. This alumina hydrate is the effective agent of coagulation, and is said to be insoluble by water and, therefore, harmless, even if it passes through the filter into the effluent. On the other hand, we have the concurrent testimony of chemists and physicians that alumina hydrate is soluble by acids, that lactic acid is present in the human stomach, and that alumina hydrate is as dangerous a form of cumulative mineral poison as arsenic, bismuth or mercury.

The evidence of chemists and physicians is so nearly unanimous as to the effect of repeated small doses of alum in impairing digestion, with an attendant train of evils, that it may be safely said that the voice of the scientific world condemns the use of alum for any purpose, or in any form, in the preparation of food or drink for man or beast.

Filtration experts admit that alumina hydrate passes through the filters under usual normal conditions, and that free alum will pass the filters if used in undue proportions. Therefore, we have to do with solid facts.

Alum is injurious to man and beast, and alum, in native or disguised form, is present in water that has been chemically treated and filtered by mechanical or sand filters. Native alum gives notice of its presence by its peculiar taste; alumina hydrate, being tasteless, is a more insidous and dangerous form.

Specious arguments in favor of filtration are based on statistics of reduced number of proportion of deaths from typhoid fever, which is said to have followed filtration of public water supplies. The argument would really be stronger if claim was made for only a share of the credit, for other contemporary improvements are made, notably in treatment of the disease, and, beside, statistics based on short and limited experience are liable to be misleading; but even if filtration does lessen liability to fever epidemics, the gain in that respect may easily be too dearly purchased if alum in water impairs digestion, especially of the weak and young, and induces diseases of stomach, bowels and kidneys, affects the blood and impairs vitality, as the testimony shows that it does.

Of the total number of bacteria in water, but a very small fraction are likely to be pathogenic or dangerous. It is usually assumed by filtrationists that the number of dangerous bacteria will be diminished in the same proportion as the non-dangerous. This assumes that all kinds of bacteria are of one size and of like form, so as to pass through the filters with equal facility or diffi-

culty. Bacteriologists find great difference in size and form. Lehman and Newman, "Text-Book of Bacteriology," gives as dimensions of bacteria:

Bacterium prodigiosum	Length, 1.6 micron.	Width, 1.0 mic.
" proteus vulgarias	" 1.6 to 4.0 "	" 0.4 "
" vulgatus	" 1.6 to 5.0 "	" 0.8 "
" cyanogenes (Flugge)	" 1.2 to 3.0 "	" 0.5 "
" colon	" 2.0 to 4.0 "	" 0.4 to 0.6 "
" diphtheria	" 6.0 to 8.0 "	" 1.0 "
" cholera	" 2.0 "	" 0.4 "
" typhoid	" 1.0 to 3.0 "	" 0.5 to 0.8 "
Spirillus fluorescens (Krahl)	" 0.8 to 3.0 "	" 0.4 "

$$1 \text{ Micron} = 0.00003937 = \frac{1}{25400} \text{ of 1 inch.}$$

Evidently, a filter which would be diphtheria-germ proof might be an easy thoroughfare for typhoid germs. The texture of the real filter, therefore, is of much consequence. The slowly accumulated bacterial felt of slow sand filters catches nearly all sizes, and hence sand filtration is credited with marked reduction of typhoid.

The rapidly collected and frequently changed coagulum skin of mechanical filters is of coarser texture, and lets the typhoid germs pass, and so mechanical filters earn a bad record as to typhoid.

On page 196 of Senate Committee Compilation the reduction of deaths from typhoid fever after adoption of sand filtration in four American cities is given as 78.5 per cent., and in five cities having mechanical filtration as 26 per cent., and in Lexington, Ky., there was an increase of 256 per cent. in the four years 1895-99 over the preceding four years before filtration.

After the preceding pages were written, a new proposition was made by the filter people, but the terms have not been made public. The writer understands that it professedly promises to use iron as the agent of coagulation instead of alum. This substitution of an unknown agent for one that has become too well known emphasizes what has been said as to the system of mechanical filtration being in an experimental stage, and virtually admits that the use of alum should be avoided.

Favorable experience with iron as the chemical agent in connection with mechanical filtration is claimed at Quincy, Ill., and Lorain, Ohio, but the testimony is mostly that of employes of the company which controls the process, and consists of claims based on scant array of disclosed facts.

Filtration experts have condemned iron as a coagulant.

Mr. Fuller.—"In short, the carbonic acid in the water renders the use of ferrous sulphate, and all compounds of iron, inadmissible for coagulation, owing to the passage of dissolved iron through the

filters. To remove carbonic acid before applying the ferrous compounds would be too costly to be practicable."

Mr. Hazen.—"Iron-containing waters when first drawn from the ground are bright and clear. On exposure to the air they quickly become turbid from the oxidation of the iron and its precipitation as ferric hydrate."

"Ferrous sulphate is not readily oxidized, and for this reason has not been successfully used in water purification."

"Ferric sulphate acts in much the same way as sulphate of alumina, but has not been used in practice on account of increased cost as compared with its effect, and to the practical difficulties of applying it in the desired quantities due to its physical condition."

(Among the claims based on Quincy and Lorain experience is that of cheap production of ferrous sulphate.)

"Waters containing iron have been used as mineral waters for a very long time. Such waters have an astringent taste and have been esteemed for some purposes. As ordinary water supplies, however, they are objectionable. The iron deposits in the pipes make the water turbid and disagreeable, and, still worse, the iron often gets through the pipe system in solution and deposits in the wash-tub, coloring the linen a rusty brown and quite spoiling it. One-tenth of a part is quite sure to precipitate and give rise to serious complaint. Two or three-tenths of a part will make the water entirely unsuitable for laundry purposes, and will hardly be tolerated by a community."

Though there is much difference of opinion as to the necessity for bacterial purification of St. Louis water, there can be none as to clarification. So long as St. Louis takes water from the Mississippi or Missouri Rivers, the first pumping will be of a muddy water, but all water pumped the second time, even that which is lost or wasted, should be clear, if for no other reason than to lessen the work and wear of engines and pumps. The demand for clear water on account of hygienic, economical, business and æsthetic reasons is imperative.

PLAIN SUBSIDENCE.

The use of chemicals to clarify the water has been shown to be undesirable. The only way in which Mississippi water can be clarified without a coagulant is subsidence for a sufficient time.

The clear water seen in lakes and ponds proves that subsidence is effective, under suitable conditions. All waters of rivers and lakes have their ultimate origin in rainfall. The rain falling on a mountainous, rocky country becomes turbid, but the suspended

material is speedily dropped when the water comes to comparative rest. That which falls upon more fertile lands takes longer time to become clear and must be more nearly at rest. If the ground on which the rain falls is a deep clay formation, there is need for more time and more complete rest. Time and quiet are the essential conditions for clarification by subsidence.

The turbidity of Mississippi water at St. Louis is made up of sand, which will quickly subside, of silt, which takes longer time, and clayey matter, some of which consists of impalpable particles, which subside so slowly that a perfectly clear water is not practically obtained by subsidence, but one sufficiently clear for all ordinary purposes can be obtained.

At Washington no complaint is made when a copper ball is visible through 22 inches of water. A like standard of clearness would answer for St. Louis; and this can be done if subsiding basins of suitable depth, area and shape are provided and properly used.

St. Louis has already made two attempts to improve its water by subsidence, having constructed four basins at Bissels Point with an aggregate water area of 15.427 acres, and a drawing depth of 12 feet. These were in use from 1867 to 1894. Since the latter date they have been used but little. In 1894 six basins at the Chain of Rocks were put in service, having an aggregate area of 36,363 acres, costing $1,164,133, practically $32,000 per acre.

The present settling basins were designed to be operated by filling and drawing with an interval of rest. As the filling was done through a single inlet, direct currents and eddies prevented subsidence during the time of filling, and the drawing being through a single outlet near the bottom of the basin, mud which had partially subsided was carried out with the effluent water. By dividing the incoming water and using devices to draw from near the surface and at several points, better results could be obtained, and if the entire pumping capacity was used for filling, several hours could be added to the rest period and a further gain made. Recently the method of operation has been changed to that of continuous flow through several basins. If the motion of water could be directly forward, and if the draft of overflow weirs could be confined to surface layers, the result of continuous flow might be fairly good. But eddy currents are set up in the basins, as well as direct, and water from all depths is drawn to the outlet, and, as a consequence, very fine clay in suspension has really no chance to subside.

The result of sedimentation for an average of 60 hours is stated (page 30, Expert Commission report) to range from 65 per cent. for months of least sediment to 94 per cent. for months of maximum sediment. Three months of minimum sediment in 1900-01 give a mean of 233 parts per million; 65 per cent. removal leaves 81.5 parts. The average of three maximum months in 1900 gives 2,523 parts per million; 94 per cent. removal leaves 151.4 parts. The subsidence is, therefore, large in amount, but is far from satisfactory. The standard of admissible turbidity is, of course, arbitrary. Forty parts per million might be tolerable and 20 parts quite good.

How long subsidence would be required to obtain satisfactory results is now a matter of estimate for want of reliable information. We will assume that 24 hours' sedimentation will remove the great bulk of sediment whose accumulation would make frequent cleaning of basins necessary. That a second sedimentation for 48 hours would remove the silt, and the basins would require occasional cleaning, and that if the water is then held in receiving reservoirs for ten days, the deposits in the reservoirs will accumulate slowly. By 13 days' sedimentation in 3 distinct steps the result would practically reach a limit beyond which it would be useless to go.

For a daily supply of 110,000,000, supposing basins to be 12 feet available depth, and one-sixth in reserve, there would be required:

Preliminary basins 6, area 32.73 acres.
Secondary basins 6, area 65.47 acres.
Receiving basins 12, area 336.7 acres.

The present basins, having area of 36.363 acres, would amply suffice for the preliminary sedimentation.

It would be necessary to construct:

65.5 acres secondary basins, at $30,000	$1,965,000
337 acres receiving basins, at $25,000	8,425,000
Land and contingencies	1,610,000
Transfer of intake to Missouri River at Bellefountain bluff	2,000,000
Probable cost of sedimentation works	$14,000,000

The transfer of intake is included in estimate for two reasons: First, it would eliminate three-fourths of the probable pollution by sewage; second, Missouri River water is believed to part with the remnant of sediment, after two preliminary sedimentations, more readily than Upper Mississippi and Illinois River waters.

By the expenditure of $14,000,000 the city could have a supply of well-subsided water that will suffice, in quantity, for its wants until extension of present works is necessary. The subsided water will not be ideally perfect, for at its best it will be slightly clouded when looked at in a glass vessel, and at times there may be trace of dark color.

The quantity would be limited to the capacity of existing conduits and pumps, for it is not probable that land suitable for the purpose could be had for a much greater area of reservoir than has been estimated. As the time approaches when a larger supply will be required, new St. Louis will doubtless have developed conditions of distribution which will demonstrate that no extension of works should be made at Chain of Rocks, but that the city must resort to another source of supply for its then immediate and prospective wants. The sedimentation and pumping works will in any case retain their place and value as part of the water supply system of the city.

SUPPLY FROM MERAMEC WATERSHED.

Rain water is, as a rule, soiled by coming into contact with the ground, and needs clarification to greater or less extent. In some cases the clear water of mountain streams is of sufficient constant volume to supply towns without storage of the surplus at one time to meet the deficiency of another season; but usually such storage is necessary, and the storage reservoir may, and usually does, serve the further purpose of a subsiding basin.

New York is spending many millions on Croton dam and aqueduct to impound, clarify and convey its water supply. Boston and its neighbor cities are associated as a metropolitan water and sewage district to obtain water from Nashua River, and are building a very large storage reservoir and miles of conduit in intelligent preference to taking water from a nearer river which would need to be purified. Liverpool, Manchester and Birmingham, England, bring their water, at great cost for works, from the mountain region of Wales, and London, after long experience with filtration, is about to take steps to bring water from the Welsh mountains.

In order that the water from a catchment area may be utilized to supply a city, certain conditions must exist. Most of them are nature's provisions. The catchment area must be large enough to ensure an ample supply for a considerable future period; the elevation must be great enough to deliver water at the city under sufficient head; the climatic conditions must be reliable; the geology of the region must be appropriate to avoid mineralization of

its drainage and loss of water by percolation to great depths or by following fissures or strata to outlets beyond reach. The area must not be fertile or rich in mineral or other resources, not even affording good pasturage, lest it attract cultivation and numbers of men or animals. For storage reservoirs there must be valleys of considerable width and moderately flat longitudinal profile; the sides need to be steep and the floors impervious. Favorable sites for dams on secure foundations are requisite.

When nature, by providing these necessary conditions, has made it possible for a city to obtain a supply of pure water delivered by gravity there can be no question but that it should be preferred to any scheme which requires pumping, and much more if any treatment of the alternative supply is necessary, unless the cost is beyond the financial resources of the city.

This self-evident proposition brings the water problem for St. Louis to these two questions. Is a supply of pure water delivered by gravity a physical possibility? And is it financially possible under present or anticipated conditions?

If nature has provided a water supply for St. Louis that can be delivered by gravity, it must be found in the tributaries of the Meramec River which drain the rugged country to the east and south of that stream.

The physical features of this territory have been as fully shown in the report of the Expert Commission as available information permitted. The majority of the Commission recommended that the city adopt the gravity supply system, and in effect proposed to make use of the water of the Courtois and Huzza water sheds as the first stage of development, that of the Water Fork of the Meramec and the flow from Meramec Spring as a second stage, and development of the water resources of the Dry Fork water shed to increase the flow of the spring as a supplementary stop when needed.

The catchment areas are: Courtois and Huzza, 501 square miles; Water Fork of Meramec, 344 square miles; Dry Fork of Meramec, 383 square miles. Total 1228 square miles. In the eastern states engineers estimate the available water from a catchment area at 500,000 gallons daily per square mile. Missouri climatic and rainfall conditions do not justify so large an estimate. The Expert Commission make a conservative estimate of 238,000 for dryest year, and 382,000 for ordinary dry years as the available daily supply per square mile of the Meramec water shed, which would make:

Courtois-Huzza in dryest year	119,000,000	ordinary dry	191,000,000
Water fork in dryest year	82,000,000	" "	131,000,000
Meramec spring in dryest year	41,000,000	" "	60,000,000
Dry fork in dryest year	50,000,000	" "	85,000,000
Totals	292,000,000		467,000,000

From this estimate of available water, it appears that the Courtois-Huzza water shed, as sole source of supply, will in dryest year suffice for the wants of the city until 1922. If made a supplement to existing works the dryest year limit will be reached about 1940. If the Water Fork and Meramec Spring be added as second stage of development, the gravity supply, as sole source, would suffice until about 1950, with existing works, as a supplement, until about 1970.

The above figures are, of course, mere approximations, but they serve to show the importance of the Courtois-Huzza water shed, as the first stage of development, and its necessity to a complete scheme for the future supply of the city.

Very little is known concerning the Courtois-Huzza water shed as respects its availability for water supply. We know its existence and approximate area, that it is rugged and is very sparsely populated, 11 to the square mile in 1900. The dry season flow of streams is probably small, the floods of short duration, but of large volume. There will, therefore, be need of large storage capacity. Whether requisite capacity can be had is perhaps the most serious question involved.

Until surveys have been made the Meramec as a source of supply is a promising possibility, well worth the expense of surveys. If the result of surveys should prove that it is not practicable the expense of survey would not be lost, for until the main question is settled the possibility will stand in the way of the adoption of other plans.

Full and satisfactory answer to the question as to physical possibility cannot now be made.

As to the probable cost of developing a gravity supply, assuming that it is feasible, we have the estimates made by the Expert Commission, Appendix "G," page 193. These estimates were for the development of the Water Fork and Meramec Spring. To make a rough estimate for the Courtois-Huzza we may assume that the proportion of pipes, conduit and tunnel will be about the same, so that taking the Courtois line as 15 miles shorter than that to the Meramec, we obtain:

Pipe, conduit and tunnel lines	$12,400,000
Reservoirs near city	1,904,000
Pipe from reservoir to city	3,586,000
Dam, clearing, land, gate houses, etc	4,837,000
Engineering and contingencies	2,273,000
Total	$25,000,000

Allowing, as did the Commission, that accumulated fund and current revenue will contribute to construction $4,000,000, the balance, $21,000,000, would be raised by issue of bonds which would bear $3\frac{1}{4}$ per cent. interest and could be placed at par.

The interest account after 1905 will be:

$5,808,000 old bonds at 4%	$232,320
$21,000,000 new bonds at 3¼%	682,500
Total interest in 1908	$914,820

The comptroller estimates the surplus water revenue for 1902-03 at $1,027,543; therefore, the city can carry the debt to be incurred. Expected growth of revenue from surplus of $1,000,000 in 1902 to $2,750,000 in 1925 will easily retire the $21,000,000 of new issue as is required by the State Constitution.

If the Meramec Spring and Water Fork be taken as the first step of development, the amount of bond issue required would be $22,500,000 and the yearly interest in 1908 would be $963,570.

To justify the assertion that the Meramec project is legally and financially possible, the following financial statement has been prepared on recognized business principles.

It is assumed that the actual cost of gravity works will be $26,500,000, and that they will be completed and in use in 1908. It is reasonable to allow that water revenue may have contributed $5,000,000 toward construction and that new bonds bearing 3.25 per cent. interest are placed at par, to the amount of $21,500,000. The new bonds to be payable in sums of $500,000 at dates ranging from 1909 to 1927, and the old water debt of $5,808,000 to be renewed in 1904 and 1924, at the same rate of interest as the new bonds. The estimate of revenue is made at rate of $70 per million for a consumption of 110 gallons per capita daily. A liberal allowance for extension of distribution system is made in the column headed "Working Expense."

According to this statement there would be a balance of unpaid bonds in 1928, amounting to $2,500,000. This apparent deficit would probably be cared for by the probable permanent increase in the city's population resulting from the Worlds Fair in 1904, for which no allowance is made in the estimate.

FINANCIAL STATEMENT OF GRAVITY SUPPLY PLAN.

Amounts to Nearest Thousand Dollars.

Year.	Water Revenue.	Working Expense.	Interest Paid.	Total Charges.	Surplus Revenue.	Interest Received	Yearly Balance.	Paid Construction and Bonds.
							$1,540	
1902	$1,688	$853		$853	$835	$46	2,421	
1903	1,727	864	$232	1,096	630	73	3,124	$3,000
1904	1,767	879	297	1,176	591	4	719	500
1905	1,809	892	400	1,292	517	6	742	5co
1906	1,852	906	546	1,452	399	7	649	500
1907	1,895	919	693	1,612	283	4	437	500
1908	1,939	692	888	1,580	360	3	194	
1909	1,985	701	888	1,589	396	6	596	500
1910	2,032	710	871	1,582	450	3	549	500
1911	2,078	719	855	1,574	503	1	553	500
1912	2,124	728	839	1,567	557	2	612	500
1913	2,172	737	823	1,560	612	3	728	500
1914	2,221	746	806	1,553	668	7	903	500
1915	2,271	755	790	1,545	725	12	1,140	1,000
1916	2,322	764	758	1,522	800	4	945	500
1917	2,374	774	741	1,515	859	13	1,317	1,000
1918	2,427	783	709	1,491	936	10	1,263	1,000
1919	2,482	792	676	1,467	1,015	8	1,287	1,000
1920	2,538	801	644	1,444	1,096	8	1,390	1,000
1921	2,593	810	611	1,420	1,172	12	1,574	1,500
1922	2,648	819	563	1,380	1,268	2	1,345	1,000
1923	2,705	828	530	1,357	1,348	10	1,703	1,500
1924	2,763	837	481	1,317	1,415	7	1,625	1,500
1925	2,823	846	433	1,278	1,545	4	1,673	1,500
1926	2,883	855	384	1,238	1,645	5	1,824	1,500
1927	2,945	864	335	1,198	1,747	10	2,080	2,000
1928	3,008	873	270	1,142	1,866	2	1,949	1,500
1929	3,073	882	221	1,103	1,970	13	2,432	2,000
1930	3,139	891	155	1,047	2,092	13	2,538	2,500
1931	3,204	901	75	976	2,228	4	2,370	2,308
1932	3,269	910	0	910	2,359	2	2,423	

THE MISSOURI AS SOURCE OF SUPPLY.

In case a supply of pure water delivered by gravity from the Meramec watershed should be found impracticable, the Missouri must sooner or later be made the source of supply. If it must eventually be the source, then the sooner it is adopted the better for the city. Makeshifts are costly, and a city which has an assured future, as St. Louis has, and is financially foot free, as St. Louis now is, should not resort to them.

In the discussion of plain subsidence, incidental mention was made of change of intake from the Chain of Rocks to Bellefountain Bluff on the Missouri River, as part of the plan to obtain better water without use of chemicals, and two reasons were briefly given. First. It would eliminate three-fourths of the probable pollution by sewage. This is equally true of any supply from the Missouri. The proof of the statement has

been given; of the total urban population above St. Louis in 1890, 4,343,313, 74.9 per cent. were located on the Upper Mississippi and 25.1 per cent. in the Missouri watershed. Although the areas of the watersheds, Missouri 527,155 square miles, Upper Mississippi 173,518 square miles, are very nearly in reverse proportions the natural conditions ensure that the preponderance of population will remain as now. The Mississippi area will support a dense population; the Missouri area being largely semi-arid or mountainous cannot. Density of population is an important element of probable sewage pollution of drainage waters.

Second. Missouri River water is believed to be purer and more readily clarified than that of the Upper Mississippi. The movement of silt by the Missouri is manifold that by the Mississippi and silt movement is a purifying agency.

Although the Missouri below the Yellowstone always deserves its name of the "Big Muddy," it does not transport its silt burden continuously, but drops it to form sand bars and accretions along its course and takes up new material by scour of bed and erosions, thus making frequent exchanges of load, but always loaded.

If clean sand be mixed with dirty water the sand when deposited will be dirty, and of necessity the water must lose the dirt which the sand takes. The sand grains moving with and descending through the water come in contact with clay particles and organic matter which adhere to the grains and are deposited with them. While the deposit remains at rest the organic matter is decomposed and chemical changes occur.

Since there are many changes of silt burden it is not probable that any sewage pollution from Omaha will pass St. Joseph, that of St. Joseph pass Kansas City or that of Kansas City reach the western borders of St. Louis county.

The Upper Mississippi is not an active silt carrier, the Illinois carries very little; hence, the conclusion that Missouri River water is purer than the mixed waters at the Chain of Rocks.

When water is treated by a coagulant the coagulum descending through the water entangles clay particles and bacteria much in the same fashion as does sand, and it is not improbable that much of the bacterial efficiency, claimed for mechanical filters, is due to this action.

The facts considered above account for the absence of bacteria in waters once turbid after subsidence and their absence measures the efficiency of silt purification.

To develop the Chain of Rocks station, so as to get the best possible results from the present plant, the intake should

be changed to the Missouri River. But the Chain of Rocks is not a suitable location for works to supply the entire city, now or in the future. The locality lacks area of ground suitable for sedimentation works and it is at great disadvantage as a point of distribution, being at the extreme northeast corner of the city and the growth of the city will always be away from the station. New works should therefore be located on the Missouri above St. Charles and Creve Cour Lake, and be so designed as to admit of extensions as required from time to time. The system adopted for new works should be plain subsidence or slow sand filtration after subsidence. The cost of installing new works cannot be now estimated, it would certainly be greater than is herein estimated for the Meramec supply and the cost of pumping would have to be met for all time.

It has been suggested that the sand rock formation which borders and underlies the Missouri in the western part of St. Louis county might be utilized for natural filtration. The fine clay in the water renders the method impracticable, for if the water could be brought in contact with the sand rock and the rock surface kept bare the fine clay carried into the pores of the rock would soon close them and it would not be possible to reopen them or to remove the obstructed stratum.

CONCLUSION.

The foregoing discussion leads to the following practical conclusions:

First. The first step should be the passage of an ordinance authorizing and providing for surveys of the valleys of the Courtois-Huzza and Water Fork of the Meramec to determine the existence or absence of the essential physical conditions for large collecting and storage reservoirs. If these conditions are not found, then that water shed and its possibilities will be eliminated from the water problem. If they are found, then the feasibility of a gravity supply will be established, and further surveys and investigations will be in order, such as conduit routes, dam sites, reservoir areas, observations of rainfall, gaugings of streams, chemical and biological studies of the water to obtain data for reliable estimates of cost of works and to put the questions as to quantity and quality of water on a solid basis of ascertained facts. If the estimates show that the cost would be within the financial resources of the city, and the quantity and quality is satisfactory, then the water problem will have been solved, for the advantages

of a gravity supply of pure water are so great and obvious that there can be no consideration of other sources of supply.

It has been said that waters collected from a catchment area like the Croton will sooner or later be polluted to an extent requiring that they be filtered for a public water supply. This is certainly dealing in futures. A future pollution, if it comes, must be caused by the evacuations of men or animals. Anyone who has seen the water sheds of the Upper Meramec will certainly admit that nature has fully guarded the region by a poor soil and the absence of everything that would attract men or animals in considerable numbers.

Well-studied general laws protecting water supplies will still further prevent possible pollution.

Second. If nature has not provided the essential conditions in the Meramec water shed, the city should turn its attention to the Missouri River and study the possibility of plain subsidence works, to supply the future city and similar works near Chain of Rocks, to meet present needs and to supply part of the city in coming years.

Third. Slow sand filtration of subsided water will fail for lack of material to form the necessary bacterial felt. Moreover, the fine clay will choke the filters.

Fourth. Modified sand filtration must also fail for lack of film-forming material, after coagulation; use of coagulant would be necessary for months at a time, entailing much expense and positive injury to the water for many uses, and any astringent chemical, with alum or iron base, is not healthful, no matter how small the quantity.

Fifth. Mechanical filtration, on the scale required at St. Louis and with exceedingly turbid, fine clay bearing water, is no more than an experiment. Since the method requires the use of a coagulant the economical and hygienic objections to use of chemicals have full force, and the method should be rejected. The method is held in proprietory control through patents covering details.

Sixth. The water works must remain the property of the city and be maintained and operated by the city.

Seventh. Water revenue must be carefully managed on sound business principles.

Eighth. If so managed the revenue will be sufficient to carry interest and pay the principal of the sum required to construct a new supply system.

Ninth. The State of Missouri should by appropriate legislation define the rights of individuals, corporations and cities to the use of water and prevent its pollution.

Tenth. The interests of the city will be served by the adoption of a definite policy at as early a date as is consistent with careful consideration, and by energetic action to carry the adopted policy to the result of improved water. Hesitation and makeshifts are costly.

DISCUSSION.

Mr. Edward Flad.—The main conclusion reached by Mr. McMath is that the city should appropriate funds for surveys and plans and estimates for a supply of water from the valley of the Meramec. This conclusion follows naturally from the assumption that the water furnished would be "so pure as to require no treatment to fit it for use," and the further assumption that mechanical filtration of our present supply "is too uncertain as to practical results . . . . to justify its adoption for St. Louis."

The writer believes that neither of these assumptions is well founded. The writer is of the opinion that the water to be obtained from the valley of the Meramec, with the construction of large impounding reservoirs, as contemplated, would be practically clear most of the time, but would otherwise be very little, if any, superior to unfiltered water from the Mississippi River. As a potable water, filtered water from the Mississippi River would be very much superior to unfiltered water from the valley of the Meramec.

The relative density of the population, or the comparative number of people per square mile of area on two different watersheds, furnishes, under ordinary conditions, a fair indication of the relative purity of the waters to be obtained from same. The valleys of the Meramec which it is proposed to utilize are the Courtois-Huzza, having in 1900 a population of 11 to the square mile, the Water Fork, a population of 14.5 per square mile, and the Dry Fork, a population of 27 per square mile.* Combined, they have a population of 20,840, or an average of 17 people to the square mile.

These valleys may be "sparsely populated," but the population is almost twice as dense as the population in the valley of the Missouri River.

The population, both rural and urban, on the watershed of the Missouri River is 9 to the square mile, that of the Illinois River

*See Report of Commission of Hydraulic Engineers, 1902. Page 50.

is 127 to the square mile and that of the Mississippi, above the mouth of the Missouri and exclusive of the Illinois, is 33 per square mile. The population of these three areas combined averages 19 to the square mile.*

Owing to the location of the intake on the west shore of the river, probably 75 per cent. of the water taken into the intake tower of the St. Louis Water Works comes from the Missouri River, the waters of which travel along the west shore, and only a very small percentage from the Illinois River, which flows along the east side. Assuming, however, that a thorough mixture of the waters resulted before they reach the intake, we would be drawing water from a drainage area having a population of 19 to the square mile, or, if we should place our intake on the Missouri River, only 9 to the square mile, as against a population of 17 to the square mile from the valley of the Meramec. Moreover, the pollution of the Meramec Valley would reach our impounding reservoirs fresh and in active form, and, the watershed being comparatively small, a single source of pollution might endanger the whole supply, while the greater part of the pollution in the valleys of the Mississippi and Missouri is subjected to weeks or months of chemical change and bacterial nitrification.

In drawing water for domestic consumption for the City of St. Louis from the Mississippi River, the danger from pollution due to the concentrated discharge of some sewage-laden branch above the intake is more to be dreaded than in infinitely larger discharge of sewage hundreds of miles above.

In 1895 the intake was removed to the Chain of Rocks, in order to avoid pollution from creeks discharging above the former intake. Since this time the water furnished by the St. Louis Water Works, though often dark in appearance and containing objectionable amounts of suspended matter, is not as black as it has been painted, when judged by its effect on the health of the community.

Laboratory tests of water are valuable indications, but the daily test furnished by the thousands who drink the water furnishes the best information as to its potable qualities. It has been generally agreed upon by the scientific world that the typhoid fever death rate is the best indication of the degree of contamination of a water supply (the report of "typhoid cases" is not considered reliable for the purpose of comparison). Judged by this standard, we find that St. Louis water, in its unfiltered state, was better, during

*Calculated from census of 1900.

the five years from 1895 to 1899, inclusive, than the water obtained from the drainage areas and impounding reservoirs by Boston, Baltimore and San Francisco, and but little inferior to the water obtained by New York City from the Croton Valley. The average annual number of deaths per 100,000 population for the five years from 1895 to 1899, inclusive, was 32 for Boston, 37 for Baltimore, 32 for San Francisco, 22 for St. Louis and 17 for New York City.* All of these cities except St. Louis obtain supplies from drainage areas in a manner similar to that proposed for St. Louis from the valley of the Meramec.

Mr. McMath claims that it is "dealing in futures" to say "that water collected from a catchment area like the Croton will sooner or later be polluted to an extent requiring that they be filtered for a public water supply." The difficulties which New York has encountered in preventing excessive pollution of its water supply are well known. It is acknowledge by those best entitled to an opinion that the water from the Croton is not satisfactory in quality, according to modern standards.

Many prominent engineers have for years past recognized the desirability of filtering the supply from the Croton.

As an evidence of the presence of this sentiment, we find in the report of John R. Freeman, under date of March 23, 1900, to the Comptroller of New York City, on "New York's Water Supply,"† the following: "I venture to express the belief that twenty years hence the public will have become educated to demand a higher standard of purity in public water supplies, and that all future work should be laid out with a view to filtration ten or twenty years hence of all water entering the distribution system. . . . . Personally, I believe that with complete meters and proper waste restriction filters could be properly advised at once for the Croton supply."

In the report made to "The Merchants' Association of New York City," under date of June 15, 1900, by the "Engineering Committee," which consisted of the following well-known engineers, to wit: Thomas C. Clarke (chairman), Rudolph Hering, Edward P. North, H. Haines, D. McN. Stauffer, H. G. Prout, E. E. Olcott, Henry R. Towne, D'Le Roy Dreasser and R. R. Bowker, we find the following:‡

"We consider the time to have arrived when the surface waters of the Croton, Bronx and Long Island watersheds should be

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*See Annual Report of Water Commissioner for year ending April, 1901.

†Page 12.

‡Page 54.

filtered. It is not so much the occasional turbidity and unpleasant taste of these waters which demand this improvement, but the frequent high percentage of bacteria contained in them, ... The evidence in hand, connecting certain diseases with water supplies exposed to occasional pollution, as are the Croton, Bronx and populated parts of Long Island watersheds, is now so strong that it is no longer questioned."

What better evidence could be asked for to prove that the prediction that water catchment areas like the Croton will, sooner or later, require filtration is not "dealing in futures"?

Assuming that further investigations and surveys should demonstrate that all of the conditions for an abundant supply from the valley of the Meramec are as favorable as those who are now advocating the plan hope to find them, it would require, to carry out the scheme, a preliminary investment by the City of St. Louis of $26,500,000, according to Mr. McMath's estimate, or of $31,000,000, according to the estimate of the Expert Commission. On the other hand, we have the proposition to filter the water supply from the Mississippi River at an expenditure for a filter plant of $1,700,000, with an annual cost of operation, exclusive of interest and sinking-fund charges, of $150,000 to $180,000, according to the amount of coagulant used, based on our present average consumption of 67,000,000 gallons per day.

If such a filter plant can be operated successfully and satisfactorily, then the city should build the filter plant rather than spend from $25,000,000 to $30,000,000 in developing the Meramec supply, and, if that conclusion is correct, then there is no further need for surveys or investigations of the valley of the Meramec.

Objection is made to the filter plant on account of the necessity of using a coagulant. There is a strong popular objection to the use of alum,* which is, however, founded largely on prejudice and ignorance. "We want no chemically treated water; alum is an astringent and will poison the people—it will render the water unfit for boiler purposes." These are the stock arguments against the filtration plant.

How do a proper interpretation of the chemical action which takes place and the experience of existing plants bear out these predictions? True, alum is an astringent, but with only reasonable care no alum remains in the filtered water. Nor is it necessary, in our case, to proportion the amount of alum to suit the varying

*Correctly speaking, sulphate of alumina, sometimes called "filter alum," is used.

amounts of carbonates of lime and magnesia present in the water. It is necessary only to add sufficient alum to bring about coagulation, and this amount is independent of the quantity of carbonates present, if only this quantity is sufficient to decompose the alum required. The water at St. Louis will at all times decompose from 8 to 20 grains of alum per gallon of water, and a maximum of 4 grains of alum would be required for filtration.

As applied to alum filters for residences or hotels, the objections to the use of alum have considerable force, because no regulation is provided whereby the number of grains of alum introduced per gallon can be definitely regulated; but in a city plant, where a known and definite quantity of water is being pumped, no difficulty is encountered in so regulating the addition of alum as to insure the absence of free alum in the filtered water.

When the required amount of alum is added to our water, which contains at all times considerable quantities of carbonates of lime and magnesia, a chemical change takes place, forming aluminum hydrate and sulphates of lime and magnesia. A small amount of carbonic acid gas is set free. The aluminum hydrate, so formed, is insoluble in water and takes the form of a floculent precipitate. It is taken out of the water in part in the settling basins and the balance is removed in the filter. The filtered water then has suffered no change, except that a portion of the carbonates originally existing in the same have been changed to sulphates, which are entirely harmless, there has been a slight increase in the amount of carbonic acid gas and the mud and bacteria have been removed.

All the direful predictions of injury which is supposed to result from the daily introduction into the human system of even minute quantities of alum have no force whatever, because with only ordinary precaution the filtered water will contain no alum.

As an illustration of the amount of alum required, we may compare the quantity used in filtering water with the quantity used in baking bread with alum baking powders. In baking a loaf of bread weighing 14 ounces with an alum baking powder, about 30 grains of alum are introduced with the baking powder. This amount of alum would suffice for the clarification of from 10 to 60 gallons of water. There is also this distinction, that in using alum baking powder the aluminum hydrate remains in the bread, whereas in the purification of water with alum the aluminum hydrate is removed by the filter.

Should, however, a trace of the aluminum hydrate remain in the water, even under careful operation, it is safe to assume that

not more than 2 per cent. of the original amount would remain. In a gallon of water this would correspond to the amount contained in 1-500 to 1-3000 part of a loaf of the aforesaid bread. Would even Mr. McMath hesitate to trust to his digestive organs a so highly attenuated shadow of aluminum hydrate?

The successful and satisfactory operation of mechanical filters on water similar to that obtained at St. Louis furnishes reliable evidence as to results which might be expected here.

More than twenty-five cities in America are using alum for purposes of water clarification. Some of them have been using alum for more than ten years. Among those now using alum may be mentioned Kansas City, Mo.; East St. Louis, Ill.; St. Joseph, Mo.; Cairo, Ill.; Davenport, Iowa; Vincennes, Ind.; Atlanta, Ga.; Lexington, Ky., and Chattanooga, Tenn. A 32,000,000-gallon filter plant, designed to operate with the use of alum, has recently been completed at Little Falls, N. J. The cities of Louisville, Cincinnati and New Orleans, after extensive experiments, have practically adopted the same system. The plant at Louisville, having an immediate capacity of 37,500,000 gallons, and designed for an ultimate capacity of 75,000,000 gallons, is at present under construction.

In support of the statement that the filter plants operating upon water similar to ours are producing satisfactory results, quotations from letters received some months ago are offered, as follows:

Mr. C. J. Borden, Mayor of St. Joseph, where for about four years they had been filtering with alum water taken from the Missouri River, writes: "Since the installation of the filter plant now in use the water has given very good satisfaction, both for family use and for use in steam boilers. I have heard no complaint about the alum. . . . . The water is clear and I have never heard any complaints of its being unwholesome. . . . . The water, so far as I know, is giving perfect satisfaction."

Mr. M. C. Wright, Mayor of Cairo, Ill., where for more than a year they had been filtering with alum the water from the Ohio River, writes: "We certainly consider the filtration as nearly perfect as possible; in other words, we find no objection whatever to the water they have been giving us since the filter plant has been put in operation."

Mr. M. M. Stevens, Mayor of East St. Louis, where for a year and a half they had been filtering with alum water taken from the Mississippi River, writes: "Would state that this plant went into operation in April, 1901, and the water through same

has been practically clear at all times, and, so far as I know, entirely satisfactory to the consumers of water in the city. The water is soft and seems to answer all purposes satisfactorily, and is used by our factories in steam boilers, and also in the locomotives of the railroads entering East St. Louis."

The capacities of the above mentioned plants are as follows: St. Joseph, 7,000,000 gallons; Cairo, 3,000,000 gallons; East St. Louis, 9,000,000 gallons per day.

It has also been urged that the use of alum would render the water unfit for boiler purposes. Letters addressed to large consumers of water for boiler purposes in East St. Louis, Kansas City and St. Joseph have brought forth the following replies:

A total of twenty-four answers were received. Ten consumers claimed that the water was better for boiler purposes than it was before alum was used, eleven consumers merely stated that no injury had resulted from the use of alum, and three consumers claimed that alum was not a good thing for boilers, but did not present any conclusive evidence of injury to boilers.

With the use of alum a portion of the carbonate of lime is changed to sulphates, and it is conceded that the sulphates are considered more objectionable in boilers. This change, however, is more than counterbalanced by the removal of the suspended matter. From the evidence above it appears that the objection to the use of alum on account of possible injury to boilers is not well founded.

Careful experiments conducted at Louisville, Cincinnati, New Orleans and elsewhere demonstrated conclusively that the form of filter suggested will not only clarify the water, but will, with proper operation, remove from 97 to 98 per cent. of the bacteria. It would serve, therefore, not only as a clarifying, but also as a purifying process. The efficacy of a filter plant in purifying water is usually measured by the completeness of the removal of the bacteria, and that a removal of the bacteria will result in reducing the danger from typhoid fever and other water-borne diseases is too well proven to admit of any doubt.

Opposition to the construction of a filter plant is due also in part to the erroneous belief that some individual or filter company controls patents which would put the city more or less at the mercy of the patentee. As a matter of fact, the controlling patent on mechanical filtration has expired, and there are no existing patents on details which are essential to the successful operation of a mechanical filter plant. The City of Louisville is at present building a filter plant of this type without reference to existing

patents, claiming that they infringe none. A well-known consulting engineer, who has been connected for fifteen years with the manufacture of mechanical filters and has been in the employ of some of the principal filter companies, writes as follows: "It is possible to design filters which will not only possess all the best features of filters now on the market, but which will embody improvements upon present practices and designs, all without fear of infringement of patents."

It appears, therefore, that there is no good foundation for the statement that large royalties could be exacted by parties holding patents on mechanical filtration.

In mechanical filtration the cost of the coagulant is an important item. The addition of a small amount, averaging perhaps 1 grain per gallon, is sufficient if clarification only is required, but an additional amount and more careful operation is required if a high percentage of removal of bacteria is desired. In most existing mechanical filter plants clarification is made the primary consideration, but there is ample evidence to prove that a high bacterial efficiency could readily be obtained at an increased expense for coagulant. In the estimate of cost of operation for St. Louis it is assumed that an average of not to exceed 3 grains of alum would be required per gallon of water.

The Missouri River would furnish a better water than we now obtain. It would, however, require the same treatment as the water we now obtain from the Mississippi. Filtration of our present water would furnish a satisfactory supply, and, therefore, the expenditure of perhaps $1,500,000 in constructing an intake on the Missouri and a tunnel to our present works would not now seem to be warranted. This could, however, be done at any time in the future without abandoning any part of our present pumping station, settling basins or proposed filter plant.

The next extension of the St. Louis Water Works should be built on the Missouri River, with an intake above St. Charles. This work should be commenced in the near future, in order to have the new plant in operation by the time the present plant has reached its full capacity, which condition is likely to obtain in three or four years. In all probability, temporary expedients to increase the supply from the present works will have to be adopted before a new system can be placed in operation.

St. Louis need never go further than the Mississippi and Missouri Rivers for a supply of potable water. Government regulations forbidding the discharge of objectionable refuse will prevent

excessive pollution as the country becomes more thickly populated, and artificial purification will remove the last vestige of contamination.

Mr. Robert Moore.—The thanks of the Club are due to Mr. McMath for bringing to the front, as he has so forcibly done, the problem of the future water supply of St. Louis.

No problem affecting the material welfare of the city is of greater importance, and it should be kept continuously before the people until the right solution is reached and the works which this solution demands are put into execution. I must, however, take exception to some of the conclusions reached by the author as being broader than the facts will warrant.

Of these the first is his absolute condemnation of the use of alum or any other coagulant as a means of clarifying water. This conclusion is based upon the cost of such coagulation, upon its adding to the hardness of the water, but mainly upon the alleged injurious effects of alum, when so used, upon the health of those who drink it. Without taking time to go into these objections in detail, there are certain facts which seem to contradict this conclusion and to suggest that a re-examination of the premises is in order.

As regards the cost, we have the fact that the chief use of alum is by private water companies, which are in business solely for profit. In a few other cases, such as Kansas City, it is used by municipalities as being the least expensive method of reaching the desired result.

As regards the hardness of water, I not long ago listened to some unsolicited testimony by the manager of a railroad reaching St. Joseph, Mo., as to the very great saving to his company in the care of its locomotive boilers since the installation of the filtration plant at that city, a plant in which alum is used as a coagulant—testimony which strongly suggested that the slightly increased hardness was more than balanced by the absence of mud.

As for the alleged injury to the public health by the use of alum as a means of clarifying public water supplies, I must say that, notwithstanding the widespread opinion to which the author appeals, I have never yet been able to find a single tangible fact upon which this opinion is based. As stated by Mr. Fuertes in his work entitled "Water and Public Health" (page 203), "There are now hundreds of these filters in use in small municipal water supplies, where the charge of the chemicals is not carefully watched, and yet there is not recorded a single instance where it is proven

that the health tone of the community has been lowered by the use of water filtered with the aid of alum."

To the same effect is the testimony of our own local chemists, Dr. Enno Sander, Prof. W. B. Potter, Prof. Keiser, of Washington University, and others, who, in a statement over their signatures, printed in the St. Louis *Republic*, January 26, 1903, say that, as a result of chemical considerations, as well as actual experience in numerous cities and towns in this country and Europe where aluminum sulphate is used as a coagulant, no actual injury is wrought by such use, either to the life or usefulness of boilers or to the health of either man or beast. Until, therefore, some well-attested facts are produced in its support, the popular fear of injury to the public health by the use of alum to clarify the water supply must be dismissed as baseless, and the question of its use or disuse decided upon other grounds.

Nor can I, as now advised, join the author in the belief that "it is almost certain that St. Louis could obtain an ample supply of pure water delivered by gravity at a cost within the city's financial ability," the source of such a supply being, as he states later, the watershed of the Meramec River.

In any project of this kind there are several elements to be considered. Among them are the quantity and quality of the water and the cost of obtaining it. In the matter of cost, in the absence of actual surveys and estimates based thereon, no statements can be made which are much better than guesses.

And in default of a long series of gaugings of the actual run-off of the Meramec River and its tributaries, and in view of the question of the possibilities of storage in a country so fissured that one branch of the stream—the Dry Fork—at times disappears, all estimates of quantity are in like manner open to serious doubt.

Even in the matter of quality the sparsely settled condition of the watershed to-day may easily lead to over-confidence. The recent epidemic of typhoid fever at Cornell University is a demonstration of how quickly a small stream may become dangerously polluted. And, coming nearer home, we find that the drainage from the mining camps and stamp mills which have followed up the lead developments of the last fifteen years in the watershed of Big River, one of the tributaries of the Meramec, have hopelessly polluted what was, not long ago, a pure mountain stream.

In a case like this, where it is proposed to take the water of a comparatively small stream, continued purity can be secured only by a strict and constant policing of the whole watershed, such as is hardly possible except where the city becomes the actual owner.

Where this is impracticable, as it is in most cases, the only safety lies in filtration. In the case of New York City, which takes its water from the Croton watershed, this necessity is rapidly coming to be recognized. But, if filtration is necessary, the larger stream affords the greater guaranty of quantity, with, in most cases, an equal guaranty of purity in the effluent.

The whole problem, however, is one which should be taken up and studied exhaustively in all of its phases. And in so doing the effort should be not only to provide for the needs of the city of to-day, but to lay out a plan which shall provide for the needs of a large territory now outside of the present city limits, but which will certainly be within the limits of the metropolitan St. Louis of 1950.

Mr. S. Bent Russell.—It would seem that the main question at issue here, and the one upon which engineers will differ, is this: Which is the better water for a city? On the one hand, a water taken from a river which drains a large territory (part of which is thickly populated) and afterwards filtered artificially; or, on the other hand, a water collected during rainy seasons from a comparatively small watershed, impounded in a reservoir and stored for use during dry seasons without filtration. From a sanitary standpoint, it is my belief that the majority of the best authorities of to-day favor the former water. Personally, I would incline to this opinion.

For one thing, the former water is really a varying mixture of water from many sources, and so would, on the average, be safer for the average human constitution. From an evolutionist's standpoint, the best water for the average man would be an average of all the waters drunk by his progenitors. Water taken from the channel of a great river would seem to come as near to this ideal as could be asked. That filtration is a bar to the spread of such diseases as could be carried by water has been pretty well established, as Mr. Flad has shown.

On the other hand, we find it is known that large natural lakes will furnish pure water. From this comes the common but mistaken belief that small artificial lakes can be depended upon for pure water. Now, experience has shown that only with the most favorable conditions will water exposed to sun and air continue to purify itself. The greatest care and precautions are necessary to prevent vegetation, and where we have vegetation decay will follow and the quality of the water will suffer. I will not dwell on this point, however, as Mr. Flad has already shown that the belief is growing that few natural waters should be used without filtration.

In comparing waters, the question of sentiment should perhaps be considered. One says that he would not drink water that had been extracted from sewage, even though it stood all known tests for purity. Of course not. Most of our people will not eat soup after finding a fly in it, but every man who eats soup which he has not himself prepared knows that he must often unconsciously eat soup from which the unfortunate fly has been removed. It will be many years before men will refuse water from the Mississippi for sentimental reasons, if it be agreeable to the eye and taste.

Now, a word as to cost. We often hear it said by thoughtless citizens that the cost should not be considered in connection with the water question. This is, of course, idle talk. What farmer would carry his pail to a spring a mile away to get pure water if he had a stream at his door which supplied his family's wants without any known evil effect on their health? That an ideal water is desirable for a city goes without saying. We must come as near to it as is wise and expedient under the prevailing circumstances. Every city should consider the water question mainly as a commercial one. The expenditure for pure water must not be out of proportion to the expenditures for other utilities, after taking all conditions into account.

Passing from these more general considerations to the alum question, it would seem to me that the author has not fairly and impartially weighed the pros and cons. The arguments used by him are those of an advocate attacking the use of coagulants.

Mr. Flad has, however, presented the arguments defending the use of alum. I think a fair consideration of the points made by both would not sustain the author's extreme position that the use of coagulants should be set aside as out of the question for St. Louis. A fair consideration would lead to the conclusion that the use of alum with filtration may be depended on to improve our water to a great extent. Whether the process will purify water as successfully and thoroughly as slow sand filtration can now be determined only by experimental work, as it has not yet been demonstrated by actual practice on a large scale.

In other words, while many towns are now using the process, in none of them has any effort been made to get water of extreme organic purity, like that which slow sand filters are known to give, as has already been stated in this discussion. We may note here that it has not been shown that, in the case of any town having water like ours, the process has failed to give whatever degree of purity was demanded of it.

To take up another point. The author assumes in his paper that water from the Mississippi will not be safe unless it is filtered to the high degree expected of the slow sand filter. It would seem to the writer that it is an open question whether such thoroughness is essential at this period with the supply not more contaminated than at present.

In closing, I would say that the author's first conclusion, which calls for further expenditures in surveying the watersheds of the Meramec as the first step to be taken, does not seem to me to have been demonstrated in this discussion. In a case of this kind the burden of proof must fall on those who would choose to abandon the present source of supply. They must show that the present source of supply cannot be utilized, and this, it appears, they cannot do without further information than is now at hand. If the present plant can be utilized, its use should be included in any comprehensive plan for the water supply of St. Louis.

Mr. H. A. Wheeler, E. M.—Mr. McMath starts out correctly in stating that alumina hydrate is insoluble in water, yet he subsequently alludes to it as a dangerous, cumulative poison, and states that it is soluble in the lactic acid that the stomach contains. Assuming that this statement is true (though there is reason to believe, if not positive assurance, that it is not a cumulative type of poison) it has no bearing on the use of alum as a coagulant. For there is no question as to the insolubility of alumina hydrate, while its jelly-like condition causes its effectual mechanical arrest by the filter bed. Hence, there is no alumina hydrate to be found or considered in the effluent water. But it is possible to have an excess of alum or sulphate of alumina, and this no doubt is frequently to be found in the waters from private filters, where a fixed rule is followed for adding the alum, without regard to the variation in the amount of carbonates present. It is also true that it would be a serious item of expense to employ a chemist to determine the carbonates, in order to regulate the amount of alum permissible, in a private filtering plant. But the expense of a chemist and bacteriologist, constantly examining the water, would be an insignificant item of expense in the water department of a large city like St. Louis. It also happens that the St. Louis water never contains less than 7 grains of carbonates of lime and magnesia, and sometimes as high as 18 grains per gallon during low water. As Mr. McMath admits that only from 3 to 6 grains of alum are required for St. Louis water, or an average of 4 grains per gallon of alumina sulphate, there will *always be a decided excess of carbonates, and hence there can be no free alum or sulphate of alumina in solution,*

as only 3 grains of carbonate are necessary to completely decompose the 4 grains of alum. There is, therefore, no risk whatever of alum poisoning in the St. Louis problem, even if a mechanical rule of using 4 grains is followed, instead of having the proper quantity determined each day by a chemist.. This latter should be done, if for no other purpose than to avoid a needless waste of alum by using more than is necessary, as a chemist could readily save his salary in a month by determining the minimum amount required as the amount of silt varies.

As regards the Courtois-Huzza watershed, which is not only an essential but the most important of the Meramec basins, there is already an extensive series of lead mines scattered throughout its headwaters. While it is true that these mines to-day are largely of the surface or "patch" type of "diggings," and are important lead producers only under the stimulus of an active market, this same remark could have been equally applied to the St. Francois county basin less than fifteen years ago. Yet to-day this St. Francois district has grown into one of the largest lead producers in the world, since the discovery of the deep disseminated deposits of lead, with a series of new, growing, populous towns and lead mills scattered along its rivers, so that the waters that were pure and wholesome ten years ago are to-day the most polluted in this state. As far as geological evidence and mining experience can predict, the next twenty years will see a larger development of the deep disseminated lead mines in the Washington county portion of the Courtois watershed than now exists in the adjoining St. Francois county, with a consequent hopeless contamination of the now pure waters. In fact this bright future has already greatly enhanced the value of lands in this Courtois basin, so that tracts that could have been purchased for $3 to $20 an acre ten years ago are now selling for $50 to $100 an acre, and are almost sure to go very much higher. This is going to very greatly increase the cost of the reservoirs should the Meramec scheme be favorably considered.

A still more dangerous and uncertain factor in the entire Meramec project, which applies to all three basins, is the very great uncertainty whether large dams are possible in that country. For the formation is mainly limestone of very great age. During the enormous geological period that this area has been dry land and subject to chemical erosion, extremely numerous channels or crevices have been opened throughout the formation. Sometimes they follow faults or lines of fracture, but more frequently form

along the joint and bedding planes that pervade these limestones. These openings or channels vary from mere pipes a few feet or so in diameter, to large caves of great length, and again are narrow crevices or sheets only a few inches high, but of very great width where a bedding plane is followed. The bulk of the Meramec River water issues from one of these limestone pipes or channels or the Meramec Spring.

The backing up of the water by dams in this formation is liable to change the flow from a surface stream to an underground stream that may issue at some distant point below the dam. Nor can these underground channels be discovered with any certainty without actual trial, as has been found by costly experience in the St. Francois county district, which is also a limestone region.

As the topography will demand high dams to secure any considerable storage area, the resultant pressure is liable to cause the present surface water to flow through these underground drainage channels to other outlets, and thus defeat the scheme.

Mr. J. J. Kessler.—An analogy to the prejudice existing against the use of alum-filtered waters is found in the case of the alum baking powders. It is not at all unusual to see a notice in the daily papers referring to cases where harm has resulted from the use of alum baking powders. Strong proof has been brought out to show that these notices are for the most part advertising matter, paid for by the baking powder trust, who control the cream of tartar market and are therefore interested to see that no other but cream of tartar powders are sold.

The evidence which has been responsible for the general feeling against "alum powders" seems, therefore, to be of little value.

Whether aluminum hydroxide is injurious to the system in the extremely minute quantities in which it may be soluble in water is a question on which much light could be thrown by such experiments as Dr. Wiley, Chief Chemist of the United States Agricultural Department, is about to undertake.

He intends to select a number of healthy young men and feed them on different adulterated and impure food products, carrying out the tests for a length of time and under conditions which are intended to afford much valuable information.

Water containing whatever minute quantity of aluminum hydroxide it can dissolve under different temperature conditions and with different other substances present can be easily and accurately prepared, and it should take very little time to ascertain whether it has little or no effect on the system, or whether, as has

been stated, it is as violent a cumulative poison as lead, arsenic or bismuth.

Mr. N. P. Simin, C.E.—In 1897 the writer studied waterworks and water purification in different cities of the United States, and, through the courtesy of Mr. M. L. Holman, C.E., he has acquainted himself with the waterworks of St. Louis.

The writer has arrived at the general understanding that small cities, which have already built their waterworks, do not encounter the difficulties in regard to water purification which large cities are encountering. This is probably due to the fact that large cities aim to place their waterworks in more advantageous economical conditions than do the small cities. This, however, does not prove that large cities may not be as successful as small cities. What has been possible for the city of Quincy, Ill., using water from the Mississippi, should be possible also for St. Louis. The writer has given much thought, for instance, to the great difference of the attitude occupied by large and small American cities in regard to the question of fire-protection waterworks. There are many cases where small American cities have quite easily built excellent fire-protection waterworks, the same waterworks plant successfully serving for the household and for fire protection. On the other hand, it is a fact that many large cities, having abundant water supplies, can no longer depend upon extinguishing their fires directly from fire hydrants, and are obliged to introduce steam fire engines, drawing their water from the mains, or to build separate waterworks, designed only for fire use, such as are described by Mr. John C. Trautwine, Jr., C.E., in his recent paper read before the Engineers' Club of Philadelphia.

Generally speaking, the writer is of the opinion that everything which is possible for small cities should be possible also for large cities, and he wishes to apply this thought also to the water question of St. Louis.

Through his acquaintance with American water purification plants and with American literature on this subject, and also through his personal experience in Russia, the writer knows that the American method of water purification can always give excellent results. On the other hand, the English method of water filtration cannot always give good results. The experimental work of the new English filters in Moscow, in the spring of 1901 and 1902, was unsatisfactory, the water remaining turbid. The same sometimes happens in Warsaw, St. Petersburg, Bremen and other European cities.

Since August, 1902, the city of Wiesbaden has been purifying its very muddy river water by means of rapid sand filters of the system of Kröhnke without coagulation, the water being subsequently ozonized, which makes it sterile and sparkling and gives it a delightful taste.

The writer thinks that the results attained by Quincy and Wiesbaden can be easily attained by St. Louis.

Being insufficiently acquainted with the local conditions of St. Louis, the writer can make only some general suggestions, viz:

1. The whole matter of water purification in St. Louis should be subjected to a permanent, competent scientific control.

2. Understanding that there is in St. Louis no available water which could be used without filtration, the writer believes that St. Louis could advantageously use the Mississippi water, which many other cities are successfully using.

3. Plain subsidence of the water, without coagulation, could be used as a preliminary process, facilitating the subsequent purification.

4. Filtration of the water could be accomplished according to the American method with preliminary coagulation, which, under the given conditions, could do no harm. Coagulation should be followed by sedimentation. The surface of the filter bed should be washed as frequently as possible.

5. In regard to the coagulation of the water, the writer would recommend the following method: The coagulant should be used in the settling basin *only to such an extent as would be necessary for removing the turbidity of the water. As to the bacteria, their removal should not be the aim of coagulation and filtration.* After these processes the writer would recommend:

6. To use *ozonization* as a final process. This process would kill all bacteria remaining in the water, rendering it sterile. It would also charge the water with oxygen, thus improving its taste. Water purified only by filtration is always low in oxygen and does not have a fresh taste.

Believing such a method to be applicable to the purification of the water of the Mississippi, the writer thinks that the introduction of the ozonization of water would reduce to a minimum the expense of coagulation.

In order to assure a proper solution of the question of water purification, the writer deems it advisable to arrange for preliminary experimentation, which, conducted under strictly scientific control, would show all the details of the question and would make a precious contribution to the world's literature of waterworks.

The writer thinks that water purification methods should always be subject to scientific control, and, therefore, that the purification of a city water supply by house filters is inadmissible.

Mr. John W. Hill.—Mechanical filters, when used with a chemical, I do not think can be shown to be an unqualified success. As a rule the amount of coagulant applied with these filters is not sufficient to injure the water by reason of undecomposed chemical in the effluent. Such observations as I have made of mechanical filters using sulphate of alumina as the coagulant indicate that the amount of chemical applied is usually too low to produce any injury to the filtered water or to produce a satisfactory reduction of the bacterial and turbidity contents of the water.

An instance is recorded of a waterworks which was using a system of mechanical filters, and supposed to be using sulphate of alumina as a coagulant. At the time of purchase eleven barrels of chemical was furnished with the filters, and four years later, when I visited the works, seven barrels of the original number still remained unused. The filters were being worked at the rate of 190,000,000 gallons per acre per day. The manager explained that there was a local prejudice against the use of alum, and, in his opinion, it was not necessary, anyhow. The raw water was shown to contain 25,000 colonies of bacteria per cubic centimeter and the filtered water contained 5000 colonies per cubic centimeter. Here no alum was used and no purification obtained. These works were supplying 4,000,000 gallons of such water per day, and everybody was happy excepting the people who were required to use the water.

In another instance with mechanical filters alum was being used at an average annual rate of $\frac{1}{5}$ grain per gallon. No bacterial tests were made, but the turbidity of the effluent water was about 15 by the silica standard. These works were supplying 6,000,000 gallons per day, and the alum was used in small doses to satisfy an agreement between the city and the water company that the water should be filtered throughout by mechanical filters with alum as a coagulant.

There is no doubt that, with a liberal use of sulphate of alumina, mechanical filters will produce an effluent that is fair to look upon, but as a steady diet I prefer water that is naturally potable or rendered so in some other way. Until after reading Mr. Flad's discussion of Mr. McMath's paper I was not aware that people who thought that water should not be purified by mechanical filtration with the aid of a powerful chemical were "prejudiced and ignorant." I have never heard anyone suggest that the

advocates of mechanical filtration with sulphate of alumina as an aid were "prejudiced and ignorant," but it has been sometimes intimated that their judgments might be slightly warped by some of the attractive features of this system of water purification. Some mention is made by Mr. McMath of the adoption by Louisville of mechanical filters and a coagulant for the filtration of the water of that city; but, in view of the considerable length of time which has elapsed since the completion of the Louisville investigations (October, 1897), and the comparatively small volume of water to be treated (37,500,000 gallons per day), remarkable speed has not been made to put the adopted system in operation. So far as statistics have been published, they fail to show improvement of the public health by chemically purified water; at least, not sufficient to remove the "prejudice" or mitigate the "ignorance" of that class of people who do not favor such mode of treatment of water intended to be used as a diet.

I regard as of great weight the experience and opinion of the German engineers on filtration, and among these, so far as my knowledge extends, the use of sulphate of alumina or any similar chemical for water purification is sternly tabooed.

I believe it is possible to so proportion the coagulant to mechanical filters that very little or none of the chemical will appear in the effluent water, but this requires a degree of skill which it is thought will be wholly unattainable in the operation of filtration works upon a large scale.

There is only one advantage which filtration with the aid of a coagulant can possibly have over filtration without a coagulant, and that is that, in times of great turbidity of applied water, it can produce a clearer effluent, but at a cost for chemicals which it is doubtful whether cities would be willing long to maintain. If the degree of turbidity intimated by Mr. McMath for purified Missouri River water should be a standard elsewhere with rivers carrying less sediment there would be no difficulty in always attaining a better clarification of water than this implies, without resorting to the use of chemicals. The standard proposed by the Medical Society of the District of Columbia, and accepted by the engineer of the Washington Aqueduct, as representing a satisfactory degree of clarification, viz, 6.25 parts per million by the silica standard, can easily be attained by plain sand filtration. It is rare indeed that the filters now operating in Philadelphia have delivered an effluent water with a turbidity as high as 5 parts per million by the silica standard, and the average is about 2 parts by the silica stand-

ard, or less than one-third the degree of turbidity which is regarded by the Washington authorities as admissible in filtered water. The turbidity mentioned above for Washington is equal to .025 by the platinum wire standard.

Comparisons have been made in the testing stations of the Philadelphia Department of Public Works, of filtration with and without a coagulant, and the data collected abundantly demonstrates that the sewage pollution of the Delaware and Schuylkill River waters is better removed by plain sand filtration without a coagulant than it is with a coagulant, and at a cost lower than it would be if a coagulant were used by at least the price of the chemical.

As a general proposition, the experience here in Philadelphia has demonstrated that it is easier to reduce the bacterial content of polluted river water than to produce an absolutely clear effluent, but as between water showing a turbidity of 1 or 2 parts per million by the silica standard, and water absolutely free from turbidity, none but an expert with a tube of distilled water or filtered water of zero (0) turbidity could detect this slight amount of remaining suspended matter.

The occasional use of a filtered water containing undecomposed sulphate of alumina may do no harm to some people, but the continued use of such water, in my opinion, will do harm to some people. So far as I have had opportunity to discuss the matter with medical men, alum is not regarded as a food, nor as a proper constituent of food. It is a powerful astringent, and an astringent should be introduced into the human system only when used as a drug and under medical advice.

The continued use of water purified by the aid of sulphate of alumina with some people is bound to lead to serious derangement of the digestive apparatus. The exact influence of water containing a measureable amount of astringency on the delicate vessels lining the alimentary canal is a question that must be answered by physiologists. That it is bound to be injurious to some people seems to me to be a proposition that cannot be seriously disputed, and there can be no better argument for the general use of a public water which is injurious to some of its people, than it is to assume that only some of the people would be affected by the continuous use of an unfiltered polluted water. The object of procuring pure water for a city is that it shall have a beneficial influence upon the whole population, or, at least, will do no injury to any part of the population.

The mechanical filter has a function. It should not be con-

demned because it has been largely introduced to purify water with the aid of chemicals; this is not the fault of the filter, but rather its misfortune. Considering the mechanical filter as an apparatus for the preliminary treatment of water, taking the place of large settling basins, it will have a utility as wide and potent as that of the plain sand filter. In this case it operates as does the plain sand filter, but at higher rates, and, as indicated, will accomplish in a short space of time what would require a great length of time with sedimentation reservoirs. Viewed from this standpoint, the mechanical filter may be made a success, but its use for this purpose excludes chemicals.

SEDIMENTATION.

Experience has abundantly shown that water can be purified by sedimentation. If water is placed in a vessel and allowed to remain for a sufficient length of time bacteria and other life disappears. Miquel, in Paris, took a bottle of raw Seine water and set it aside for several years. At the end of the time careful bacteriological tests were made and the water was found to be absolutely sterile.

In February of 1900 I collected from the fore bay of the Spring Garden Pumping Station, Philadelphia, a bottle of Schuylkill River water at a time when the turbidity was very great, but before the city had begun to conduct regular daily bacteriological tests of its water, and therefore the original bacterial content of this water is not known. By inference from the known conditions of the water during February of 1901, 1902 and 1903, it would be fair to assume that this water contained as much as 30,000 bacteria per cubic centimeter. Two years later samples were taken from this bottle of water and very carefully tested for bacterial life, and the water was found to be absolutely sterile. This test was twice repeated, with the same results, and I now regret that samples were not drawn from the bottle at different times, viz, 60 days, 90 days, 3 months, 6 months and 1 year, in order to determine at what time in quiescent sedimentation bacterial life wholly disappears from the Schuylkill River water.

Several tests of quiescent sedimentation have been made with one of the divisions of the Fairmount Reservoir. This basin has a capacity of 3,346,000 gallons, is 12 feet deep, and in the tests mentioned the basin was filled to the flow line with raw water from the Schuylkill River and then allowed to rest quietly during a period of time ranging from three to four weeks. The results of this investigation are given in the following table:

TESTS FOR REDUCTION OF TURBIDITY AND BACTERIA BY PLAIN SUBSIDENCE IN NO. 3 FAIRMOUNT BASIN.

Capacity of Basin at flow line, 3,346,000 gallons. Depth at flow line, 12 feet.

Turbidity, parts per Million by Silica Standard, Bacteria Colonies per Cubic Centimeter of Water Sample.

DAYS OF:	TEST NO. 1. 12-18-'01—1-09-'02.		TEST NO. 2. 3-21-'02—4-14-'02		TEST NO. 3. 4-21-'02—5-12-'02.		TEST NO 4. 5-19-'02—6-10-'02.		TEST NO. 5. 6-16-'02—7-11-'02.		TEST NO. 6. 7-18-'02—8-15-'02.	
Subsidence.	Turbidity.	Bacteria.	Turbidity.	Bacteria.	Turbidity.	Bacteria.	Turbidity.	Bacteria.	Turbidity.	Bacteria.	Turbidity.	Bacteria.
	175	8,500	90	24,000	12	5,700	11	1,185	12	1,000	11	1,200
1	. .	. . .	25	20,000	. .	. . .	. .	. . .	. .	. . .	. .	. . .
2	. .	. . .	. .	. . .	10	1,450	. .	. . .	. .	. . .	. .	. . .
3	127	25,000	. .	. . .	. .	. . .	. .	. . .	10	370	. .	. . .
4	. .	. . .	. .	. . .	. .	. . .	10	165	8	220	. .	. . .
5	. .	. . .	35	18,500	10	500	. .	. . .	. .	. . .	10	600
6	95	15,000	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
7	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	18	700
8	. .	. . .	25	2,650	10	145	7	300	6	185	. .	. . .
9	72	9,300	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
10	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
11	. .	. . .	30	400	12	35	4	205	13	55	8	88
12	75	3,600	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
13	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
14	. .	. . .	25	400	9	45	. .	. . .	. .	. . .	4	37
15	75	8,500	. .	. . .	. .	. . .	5	30	. .	. . .	. .	. . .
16	. .	. . .	. .	. . .	. .	. . .	. .	. . .	6	64	. .	. . .
17	. .	. . .	30	415	9	60	. .	. . .	. .	. . .	. .	. . .
18	42	2,200	. .	. . .	. .	. . .	6	25	. .	. . .	4	28
19	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
20	. .	. . .	35	250	. .	. . .	. .	. . .	. .	. . .	. .	. . .
21	33	1,150	. .	. . .	15	63	8	85	. .	. . .	8	150
22	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
23	. .	. . .	. .	. . .	. .	. . .	. .	. . .	10	15	. .	. . .
24	. .	. . .	35	975	. .	. . .	. .	. . .	. .	. . .	. .	. . .
25	. .	. . .	. .	. . .	. .	. . .	. .	. . .	7	125	9	110
26	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
27	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .
28	. .	. . .	. .	. . .	. .	. . .	. .	. . .	. .	. . .	10	105

The conclusion drawn from the subsidence tests of Schuylkill River water in the Fairmount basin, was that the time was too long to produce a satisfactory reduction of the turbidity and bacteria by this system of water purification, and that the cost of sufficient sedimentation basin capacity, when compared with the cost of works for preliminary filtration, would be prohibitive.

Some experiments by the writer on the effect of quiescent sedimentation of the Ohio River water at Cincinnati in large reservoirs indicated that thirty days' subsidence will usually effect about the same bacterial reduction as by filtration, but this is a length of time for subsidence which is usually inadmissible in the supply of water for large cities.

PLAIN SAND FILTERS.

Notwithstanding Mr. Kirkwood nearly forty years ago proposed for the purification of the Missouri and Mississippi River waters for the city of St. Louis limited sedimentation, to be followed by the passage of the water through plain sand filters, such as he found at that time in use in the European cities, it is well known to-day that, had his plans been adopted, the filters built then would not have been successful, owing to the large amount of suspended matter carried in the raw water, and had the St. Louis scheme been reduced to practice at that time, instead of aiding the subject of water purification in this country it might have had the opposite effect. Such filters as Mr. Kirkwood might have built would doubtless been as good as the filters we are building to-day, but plain sand filters are not able to receive and successfully treat, after limited sedimentation, such water as is supplied by the Missouri and Mississippi Rivers at St. Louis. Applied to waters of the eastern part of the United States, like the Potomac, Schuylkill, Delaware, Hudson and Merrimac, the problem of water filtration presents a different aspect and is less difficult of solution.

The statement made by Mr. McMath respecting the use of alum in certain cities of Holland is rather vague. So far as the writer is able to obtain information from the managers of works in that country, it indicates that, while there may have been attempts to aid the purification of water by the addition of a chemical, it is not the practice to-day, and never has been the general practice. So far as I am aware there is no city in Holland, Germany or England that uses a chemical in the purification of the water obtained from sewage-polluted sources.

Chemicals are sometimes used for the reduction of iron in ground waters, but, while considering the general subject of filtration of polluted river waters, it is fair to exclude the special efforts

that are being made in certain cities of Germany to reduce the amount of iron carried in solution in well waters.

It is fair to call attention to some errors in Mr. McMath's paper. For instance, he intimates that the plans of Sir Alexander Binnie, for bringing the water of Wales into London, exclude filtration. Mr. Binnie's report, upon the contrary, proposes that this water shall be filtered before it reaches London, and while it is at an elevation sufficient to supply, by gravity, London, or, at least, the pumping stations of the river works. Manchester does not draw its water from Wales, but largely from Lake Thirlmere, in Cumberland. Liverpool draws its water from the artificial lake formed in the valley of the Vyrnwy River, and filters it before it reaches the city.

The filtration of the Croton water supply has been very seriously considered, not only by engineers, as, for example, Mr. John R. Freeman, but by certain medical societies of the city of New York. One of the latest complaints of the quality of the Croton water comes from the German Medical Society, which, in a series of resolutions during the past few weeks, insists upon the filtration of the water before it is delivered to the consumers. I am informed that the plans of the commission now working upon the water supply of New York contemplate taking the water from the Hudson River at Poughkeepsie, filtering it and then sending it into the city.

With reference to the new metropolitan water supply for Boston, while it does not appear in the published reports that filtration of the water is contemplated as a part of the original scheme, I have no doubt that the gentlemen in charge of this work are able to state that not only has serious thought been given to the future filtration of the water from the large impounding reservoirs now being constructed at Clinton, Mass., but that experiments have been made to determine the best manner of accomplishing this. Doubtless it is the intention of Boston to use the impounded water first, and if it should appear that other cities succeed by filtration in producing water better than that supplied without filtration from the new and old impounding reservoirs, taking water from the Sudbury and Nashua Rivers, then filtration will be introduced as an adjunct of the metropolitan supply; at least, I understand that in developing the plans this possibility has been thought of.

There is very little division of opinion among engineers to-day upon the advisability of filtering all surface waters, whether from rivers, lakes or ponds, before they are offered for drinking or other domestic uses. It is not necessary that certain waters be polluted by city sewage in order to render them unfit for domestic use. A

notable instance of the pollution of what ordinarily would be regarded as very pure mountain water, is found in the water flowing into the South Platte River, from the drainage area of the South Park. Thousands of cattle are quartered in the South Park, the droppings of which are carried into the river by the run-off of rainfall on the watershed and impart conditions to the river water unfitting it for domestic use, excepting it be subjected to some form of treatment before it is distributed to the consumers in the city of Denver.

In discussing the reduction of the typhoid fever rates in cities having improved water supplies, Mr. McMath intimates that this is not all due to improvement in the quality of the water, but is affected by improved methods of medical treatment, etc. The methods of medical treatment, however, do not widely differ in the large cities, but the typhoid fever rates certainly do. There can be no doubt that the medical fraternity of Chicago will compare favorably with that of any other large city of the country, and that the most advanced methods are there applied to the treatment of typhoid fever, but during the past nine months the typhoid rates of that city have been unusually high, and the cause is largely attributed to the polluted public water supply. Can it be doubted that, if the water of Chicago was all filtered in a proper manner, such a high typhoid rate as the city has had since last September would be impossible, and this, of course, without assuming any improvement in the method of treating the disease?

The following condensed table from the results of plain sand filtration at the Lower Roxborough Filters, Philadelphia, during the past three months has been prepared to show that the turbidity of the Schuylkill River water can readily be reduced from 100 parts per million by the silica standard to from 1 to 3 parts, and the bacterial content from 5000 or 6000 per cubic centimeter to less than 100 per cubic centimeter:

LOWER ROXBOROUGH FILTERS.

1903.	Schuylkill River, Shawmont Station.		Lower Roxborough Filters, Clear Water Basin.	
Week Ending	Turbidity.	Bacteria.	Turbidity.	Bacteria.
February 7th	500	34,000	2	100
February 14th	70	12,000	3	65
February 21st	34	8,800	3	65
February 28th	8	1,400	2	46
March 7th	700	36,000	2	48
March 14th	32	26,000	5	52
March 21st	18	21,000	3	93
March 28th	130	35,000	1	140
April 4th	28	17,000	1	140
April 11th	70	36,000	1	90
April 18th	75	25,000	1	100
April 25th	15	5,700	1	98
May 2d	13	3,900	1	56
May 9th	14	10,000	1	54
Averages	122	19,414	2	82
Percentage Reduction			98.36	99.60

Continued tests show usually the total elimination of the B. Coli Communis in the filter effluents. The presence of the typhoid organism in the water cannot positively be demonstrated, but the closely allied species, B. Coli Communis, can be differentiated, and tests are constantly being made to show the relative numbers of this organism in the applied and filtered water, with the gratifying result that its presence is seldom shown in the water from the filters.

The plain sand filters at Roxborough are running at rates varying from 3,000,000 to 5,000,000 gallons per acre per day. At the Delaware River Testing Station, with preliminary filtration, the rate is constantly maintained at 6,000,000 gallons per acre per day, and at the Schuylkill River Testing Station the filters are constantly operated with preliminary filtration at rates of 6,000,000 to 10,000,000 gallons per acre per day, with bacterial and turbidity results satisfying the highest standards set for continuous practical work. The turbidities of the filtered water by the silica standard seldom exceed 3 parts per million and the bacterial content seldom exceeds 60 per cubic centimeter.

Mr. James H. Fuertes.—Mechanical filters are no longer under the exclusive control of private business concerns or corporations. The fundamental patent on the use of a coagulant in connection with filtration expired two years ago, and any city is now free to build a mechanical filter plant without paying royalties. Although, as Mr. McMath says, many of the parts composing filters are covered by patents, this does not necessarily place a city at the mercy of private companies, because filters can be built that will not infringe on any patents. There has just been completed, at Harrisburg, a nine months' test of several mechanical filters, constructed from my designs, in which no patented parts were used. The bacteriological and chemical tests of the effluents from these filters have shown as satisfactory a degree of purification as any filters the records of the tests of which have come to my attention. Working side by side with slow sand filters, and supplied with the same kind of water, these mechanical filters have averaged, during the nine months, more efficient than the slow filters, both for the removal of turbidity and the removal of bacteria, and their work has been always good when the water was worst, which is the reverse of the case with the slow filters.

While the slow filters did excellent work when the water did not contain very much clay, they failed signally in removing bacteria during times when the water was turbid. This is quite uniformly

the experience with slow sand filters in the treatment of turbid waters. In order to secure a satisfactory effluent from a slow sand filter it is essential that the applied water be nearly free from turbidity. The occasional deterioration of the water during infrequent floods is not a matter of great consequence when the storage capacity of the filtered water reservoir is relatively large in comparison with the daily consumption of water; but where the water is persistently turbid for several weeks or months each year, slow sand filters are neither efficient nor economical unless the water be clarified before passing it through the filters.

The allegations by Mr. McMath that "The evidence established that a water, once turbid, when cleared of turbidity by plain sedimentation, or coagulation and sedimentation, is biologically too pure for successful subsequent slow sand filtration," and the further statement, "By obvious inference this biological purity greatly reduces the need for further treatment by any process," should not be accepted, excepting for waters where this has actually been found to be the case. The statement, as a generalization, is too broad. It has been found, for instance, that this is not the case with the Susquehanna River water at Harrisburg. At times, when the turbidity of the raw water was as high as 1000 parts per million, the turbidity being caused by clay particles so fine that they would remain in suspension for many days, we regularly removed, by preliminary treatment, all but about 20 parts per million, and still secured excellent bacterial results in the subsequent filtration of this clarified water through slow sand filters at a rate as high as 10,000,000 gallons per acre per day. While it is true that the phenomena mentioned by Mr. McMath were observed by Mr. Fuller in the Ohio River water at Cincinnati and by Mr. Weston in the Potomac at Washington, it has not been observed during the course of the experiments under my direction at the city of Harrisburg. Where preliminary treatment can be successfully used in preparing a water for slow sand filtration, it will frequently be found to be economical, owing to the fact that the final effluent will be better and more uniform in character, and also to the fact that the lengths of the runs of the slow filters will be greatly increased and hence the cost of operation reduced.

The argument that the use of a coagulant would increase the hardness of the water and thereby enhance the cost of laundry work and steam production falls to the ground unless the Mississippi River water is too soft to receive a sufficient amount of alum

to effect clarification, thereby necessitating the addition of soda. In the discussion of Mr. Flad it is stated that the Mississippi River water will always decompose a great deal more alum than is necessary for the treatment of the water. The addition of alum, therefore, in the proper dose, cannot increase the total hardness of the water, the chemical change taking place being the decrease of the carbonates and a corresponding increase of the sulphates, or a change of a portion of the temporary hardness to permanent hardness. This slight change in the character, not in the degree, of the hardness of the water, instead of adding expense in the matter of soap and boiler operation, would, so far as soap is concerned, involve no material change from present conditions, while in the cost of producing steam it would result in a direct saving, the advantages of clear water for boiler purposes greatly outweighing the slightly greater cost of removing the sulphate scale from boilers.

Mr. Chas. Hermany.—Mr. McMath stated that the reason why the authorities of St. Louis do not proceed with the work of purifying their public water supply is "because of their unbelief." This seems to imply that they are obdurate bodies, which is not manifest. Like all municipal authorities, they desire to be properly informed. I think that the purpose of Mr. McMath is to assist in properly informing the authorities in question; at any rate, let them be correctly informed upon the subject—the development of water purification by artificial methods—and action will take the place of deliberation and procrastination.

The claims of the "Meramec" as a possible source of water supply to consideration are, principally, that the water would be delivered by gravity flow, that the expense of pumping would thus be saved and that the water would be so pure as to require no artificial treatment to fit it for public use.

The purity here claimed is largely an assumption. Insufficient evidence is furnished to sustain the claim. It seems to be an open question. . .

The author assumes that, in filtration, the formation of a "Schmutzdecke" or "bacterial felt," in simpler terms, *smut cover,* is necessary for satisfactory bacteriological results in the filtered water. The "Decke," "felt" or "cover" here considered forms only when the Western river waters are comparatively clear, and is then only a modifying factor in purification, not the principal one.

The "Decke" upon a bed of clean sand is, of course, *nil.* It begins, in cases where it forms at all, on clean sand, increases in

body or thickness until it seals, it is said, the openings in the sand at the surface, also into the sand for a slight depth, and stops filtration under moderate head or pressure. If the head or pressure is increased, the "Decke" is said to break, rendering the effluent unsatisfactory. The composition of the "Decke," when it forms, is probably slime (mucous mud) and bacteria. The author implies that the remainder of the sand layer has no function in filtration, while, in fact, every grain of sand in the layer, from top to bottom, becomes more or less coated with slime and bacteria, until purification is accomplished. This process continues until the "Decke" seals completely, whether at the surface or in the sand, when scraping must be resorted to in order to renew the activity of the filter, but in an impaired condition. This is the physical operation claimed for the "Slow Sand Filter" or the English system.

The "Schmutzdecke" (smut cover) theory found no verification in the Louisville experiments, and to but a perceptible extent in the Cincinnati experiments, and then only when the applied water was clear. Its formation is, therefore, limited to the passing of clear water at slow velocity through sand layers, with the result of bacteria arrestment. It is not a factor in the successful purification of our Western river waters, in the perfect clarification of which by American (mechanical) filters satisfactory bacteria removal is an invariable accompaniment.

In the American system, passing coagulated water through the sand, somewhat coarser sand can be used, greater velocity of water flow is practicable, and the slime (mucous mud) and bacteria are arrested upon the surfaces of the sand grains to a greater depth in the layer, until the voids at the surface and in the sand become sealed. Washing the entire sand layer is then resorted to, the filter restored to its normally effective condition and filtration resumed.

In the American system the suspended matter, including bacteria, is deposited to a greater depth in the sand layer than in the English system.

In both these operations the *friction* of the passing water over and around the surfaces of the sand grains is the primal function of arresting suspended matter, of bacteria removal and of purification. In both systems the operations are in many respects similar; but they differ in this, that in the American filter coarser sand may be used and greater velocity of the coagulated water is practicable.

The question of the comparative efficiencies and economies

of the two systems, all things considered, is here not conceded to be still an open one. If it is still open, it can be closed only by the operation of two filter works of magnitude upon the same quality of water, conducted with equal care and equal scientific precision.

The author states, in incorrect order, the processes taking place in mechanical filters, which process is (1) sedimentation, (2) coagulation and (3) filtration, and not, as stated, "first coagulation, second sedimentation and third filtration."

The author correctly states that "An expert chemist and bacteriologist must be at hand to fix the proportion; an expert must be employed to make the application." This seems to imply that an English filter is a self-regulating mechanism, which needs no attention from an expert. In the successful operation of an English filter expertness is as necessary as it is in the operation of a mechanical filter. The difference between the two lies principally in the fact that, in the case of the English filter the expert is comparatively impotent, while in that of the mechanical filter the expert is master of the situation.

The author states that "the task of adjusting the dose (of alum) to the varying conditions is admitted to be vastly more difficult at St. Louis than at any other locality where coagulation and filtration are used or have been proposed." This admission betrays an Adonis-like temperament, which lacks all the qualities requisite for mastering the situation. The promptness with which the heavier suspended matter in the Mississippi River water subsides makes it less difficult of successful treatment than that of most of our Western river waters; in the successful treatment of any of which, however, a dominating courage with adequate devices are indispensable.

The suspended solids, for successful English filters (slow sand filters), are limited by the author to 125 parts per million. By present plain subsidence, it is stated, 300 parts per million is the greatest reduction, and a second subsidence is necessary to make an English filter work successfully. No such limit exists for the American (mechanical) filter, for it can easily treat, clarify and purify water containing this degree of turbidity.

Cincinnati does not, as stated by the author, contemplate adopting the "Modified Slow Sand" system of filtration. The suggestion quoted has therefore no application in the St. Louis discussion.

Subsidence in "considerable bodies," of volumes comparable with those of "lakes," involving great length of time, is not even a conceivable project for St. Louis's case.

The fairness displayed in mentioning "Induced Natural Filtration" concedes merit to a system which has not received serious consideration in any undertaking of similar magnitude to that which is before St. Louis.

The six steps enumerated as necessary for obtaining clear and pure water from the Mississippi from the Chain of Rocks site can be diminished by one step, No. 4, second subsidence, if mechanical filters are adopted.

The suggestion to dispense with the third step (introduction of coagulant), and to substitute an "Extended subsidence in receiving reservoirs" for filtration, "if the city would be content," is a vagary which implies that the city is at sea in this enterprise.

The author noted the comparative turbidities of the waters on the Missouri and Illinois shores of the Mississippi River at the Chain of Rocks. This appears like adding so many ems to the composition of the paper under discussion, for the Illinois shore water is not in the problem. The full development of the present St. Louis system, with probably an eventual intake from the Missouri River and thence partly through tunnel to the site of the Chain of Rocks' works, would seem at present to be a logical procedure with the St. Louis problem, finance and physics being considered jointly, in which consideration, however, finance should not be given undue weight. There will be no mention made of the cost of a scheme that will prove a complete success; such success is assured by the intelligent application of the American system of water purification. The people will insist that it shall be efficient and satisfactory. If this be accomplished, the question of cost will never be adverted to.

In discussing the "Merits and Demerits of the Several Methods of Treating Water," the following statement is made: "Sand filtration has been in use for a long time and on a large scale in Europe and America. It is, in fact, nature's process of clearing water applied through filters of man's construction and arrangement. The limitations of man's work do not allow exact duplications of nature's process, such as unlimited time and great area and depth of material."

The overshadowing cosmos here invoked is embarrassing to man, for in it all there are no differentiations which constitute municipal water supplies. These, where they exist, are the results of art and science, or man's work. But whether they are imitations or originations, the disparagement to man is great when he is hauled up at the bar of nature and asked to defend his work; that is to say, to defend a specialty of his own, which nature permits but does

not herself provide, and all this because his art has municipal limitations and not cosmic splendor. An optimistic view of the question and a resolute grapple with the problem show that man has, not by imitation, but by art devices of his own, demonstrated that he can purify, per acre of sand surface per twenty-four hours, 125,000,000 gallons of water, in a space, containing all mechanism and materials, one acre in area and a depth not exceeding 60 feet, or about 45,000,000,000 gallons per annum.

In the order or differentiation of nature, a rainfall of 60 inches in depth per annum, upon a locality favorable in topography and arrangement of material, with no loss by evaporation, but with all the water filtered and conserved for use, an acre of ground will yield not quite 1,750,000 gallons per annum of such naturally purified water. The work here accomplished by nature, if compared numerically with that of man, will be as 1 is to 28,000. From this it appears that man is not altogether an imitator, but is endowed with resources of his own, which are not to be deprecated in enterprises of municipal water supply.

In addition to this, it is to be remembered that, in the case of man's works, he is at liberty to locate them where they can be most economically constructed, operated or used; whereas, in availing of those which nature provides, it is generally necessary to supplement nature's work with large and expensive artificial elaborations at great distances from municipalities and generally at prohibitive cost.

In justice, however, it is to be remarked that the limitations of man are expressed, by our author, in terms of "English filters," which are at the same time pronounced not worthy of serious consideration in the St. Louis problem, and it may be therefore necessary to add, that the comment applies to what follows upon American filters as well as to the remarks on English filters.

The author, having finally and properly dismissed the English filter from the St. Louis problem, proceeds to discuss the "Modified Slow Sand Filter." The emphasizing of *sand filter*, both here and heretofore, seems to be not altogether appropriate (for which, however, the author is not responsible); for sand or its equivalent has heretofore been an indispensable component in all artificial filters applicable to municipal water supplies, whether slow or fast.

Assuming as correct the claim, made in this paper, that "slow sand filters" can not successfully treat water containing more than 125 parts per million of suspended matter, then the rate of filtration through them can be increased by the use of coagulant; but it has not been shown that by such use the number of scrapings and

renewals of sand layer can be correspondingly reduced. In this "modified English system" increased output and cost of chemicals constitute the factors (on a given sand area) which determine the gain that may result.

The conclusion drawn from the author's paper is, that too great a reduction of bacteria by subsidence prevents the "Decke's" formation, and impairs if not prevents satisfactory results from "slow sand filtration." Experience at large does not seem to warrant this conclusion.

The clearly defined issue, between the English and American systems of filtration, seems to be that between filtering at slow rate waters of slight turbidity and filtering at high rate waters of great turbidity.

In the paper before us, some recent history of American filter studies and discussions has been rather searchingly reviewed. The witnesses upon the stand, if this ascription is permissible, have been fairly recross-examined with a resulting degree of straddling of unprecedented reach, accompanied here and there by bad logic. Notwithstanding all this, the underlying principles or correct physics involved have not been impaired in their applicability to successful water purification by this method, even in cases of water like that in the Mississippi River at St. Louis.

Mr. R. E. McMath.—After reading the discussions the author does not wish to make reply to criticisms. It was not his purpose to do more than make a non-partisan statement of the water problem at St. Louis. Taking into account the local conditions and the fact, now admitted, that the city will shortly be compelled to construct a new system of supply works, the matter seemed to the author to invite inquiry and non-controversial discussion, not so much as to treatment of water by the several methods which have been found effective elsewhere, but as a local problem for a city which, unlike most others, has choice between sources of supply as well as between methods.

From the author's point of view the most important development of the discussion was furnished by Mr. Flad, near the end of his discussion, to the effect that St. Louis must take immediate steps to construct new supply works. If it must have a new system, then the question as to source of supply is of prime importance and greatly outweighs the minor question of treatment.

Many believe that a gravity supply from the Meramec watershed is physically and financially possible. Many hold that the water from that source would be so pure as to require no treatment. In the paper the author urged full investigation.

The Meramec proposition was recommended by Benezette Williams and Geo. Y. Wisner, a majority of the expert commission employed by the city in 1901, "To carefully examine the present water plant of the city and thoroughly investigate and submit a report, with estimate and recommendation as to the most feasible manner of providing the city with an adequate supply, both present and prospective, of clear, wholesome water."

Mr. Allen Hazen made a minority report in favor of filtering, by mechanical filters, the present supply. He apparently did not grasp the urgency of the situation as demanding increased capacity, now so clearly stated by Mr. Flad.

These reports, made in January and February, 1902, left the water problem open to discussion. There seemed to be in some quarters a disposition to ignore the report of the majority of the commission and to commit the city to filtration, with use of a coagulant as an indispensable adjunct, and there is a strong sentiment against chemically treated water. The author attempted to present the matter as it appears to him, *i.e.*, as a purely local question of policy.

ANNUAL ADDRESS TO THE MONTANA SOCIETY OF ENGINEERS.

By Joseph H. Harper, President.

[Read at Missoula, Mont., January 10, 1903.*]

The past year must be regarded as one of unusual prosperity throughout the States, and one in which a marked degree of engineering enterprise is manifest, though much of it is so disguised by association with the country's financial expansion and industrial growth that its true character is easily overlooked.

The calendar period may not include the date of commencement or completion of any particular work of great importance, but a summary of what has been accomplished within a short twelve months upon the subways of New York and Boston, the East River bridge, the Panama Canal, the numerous power plants, the innumerable transmission enterprises, the extension of trolley lines, the consolidation of railroads and steamship interests, and the unparalleled expansion of industrial enterprises, demonstrates that our progress has been both real and substantial.

The conditions prevailing through the country at large are fairly indicative of those in our own State, for I am not able to report either the beginning or completion of a single engineering enterprise of great importance, and yet, when we note the numerous and extensive replacements of temporary with permanent structures by our railroad lines, the numerous and expensive improvements that have been made by our mining companies, the constant and ever-increasing developments of our industries, the growth and expansion of our power and transmission plants, we shall see that Montana has accomplished much along the lines of engineering progress.

Our President-elect, writing from Helena under a recent date, says:

"The State and Land Grant Company have completed 21 miles of canal, to cover 11,000 acres, of the dimensions following:

4.50	miles	of	20 ft.	canal.
5.47	"	"	16 "	"
5.41	"	"	8 "	"
5.62	"	"	7 "	"

"The water is taken from the North Fork of the Dearborn River, 14 miles southwest from the town of Augusta, Lewis and

*Manuscript received April 18, 1903.—Secretary, Ass'n of Eng. Socs.

Clark County, by a 20-foot canal, from which it flows into Flat Creek and follows the valley for $1\frac{3}{4}$ miles. From this it is taken in a 16-foot canal, discharging into the valley of Dry Creek, which it follows for $4\frac{1}{2}$ miles, when it enters the 8-foot canal.

"It is proposed to cover the land with proper irrigation along the above line, and then from the 8-foot and 7-foot canals distribute to the main body of 11,000 acres.

"It is further proposed to have auxiliary reservoirs, which are to be filled at the flood season of the year, to furnish water during dry seasons and for late irrigation when required.

"These reservoirs are not yet built, but there are a number of sites favorable for such construction, capable of containing water to supply all deficiencies and, when required, to cover an additional area of 22,000 acres.

"This work is in line with the most important enterprises of the State, not only in the way of increasing our products, but in securing a population that it is hoped will be a valuable acquisition, a community of men that would look for and desire an economical, fair and honest government.

"The work, so far as completed, is well done, and a credit to those who have had it in charge. Mr. Ames, of St. Louis, and his friends are the parties who have advanced the money for the project. Mr. Knox, at present of St. Louis, is the engineer who has had immediate charge and has located and directed the work.

"Like all projects of this kind in the State with which I am familiar, the feature of reservoirs is a very important factor for final success, reservoirs that will retain for irrigating purposes the water which runs to waste, and which usually exceeds in amount all that flows for the remainder of the year.

EAST HELENA SMELTER.

"The plant of the American Smelting and Refining Company, at East Helena, is probably the best equipped smelter in the State for treating all classes of custom ores.

"They have at the present time five stacks, with a capacity of 200 tons each, built under the management of M. C. W. Whitley, who retired from that position August 1st to take charge of the company's interest in Utah, Nevada and Idaho.

"Mr. E. W. Nash is president of this company, which is operating some fourteen individual smelting plants at different points in the United States, with a central office at 71 Broadway, New York.

"The East Helena plant, which is rated sixth of the smelters operated by them, has facilities as complete and extensive as any

in the country, and when in full blast is capable of handling about 1000 tons per day and furnishes employment for about 700 men.

"On Mr. Whitley's retirement, Mr. Eugene B. Braden succeeded to the management of this enterprise, with Mr. F. M. Smith as assistant.

"Under date of December 19th, Mr. Braden writes that the company have during the year installed steam locomotives in place of horse power for the removal of slag from the furnaces, and they now claim to be putting through more ore per stack than any other furnace owned by the company.

"He states that the ore receipts at present are not as large as they would wish, a condition which he attributes largely to the falling price of silver and unsatisfactory labor conditions, and expresses the opinion that there are a great number of properties now idle throughout Montana that would be at work if more favorable conditions prevailed.

"The East Helena smelter is not a large undertaking when compared with some of the mammoth concerns engaged in the reduction of copper ores, but when measured along its selected line of work, which is the purchase and treatment of all profitable ores that the market may offer, it easily becomes the largest and best equipped enterprise of this character now operating in the State.

WASHOE COKE PLANT.

"The Washoe Copper Company (Coke Department) are perfecting plans for the betterment of their plant at Storrs, near Chestnut, in Gallatin County, Mont. Of this enterprise Mr. P. M. Gallagher, engineer in charge, writes that this venture, which contemplates an investment of something like $250,000, is at the present time in the formative or constructive stage.

"Work was begun June 1, 1902, and they hope to have it completed about May 1, 1903, as considerably more than half of the work is now finished. The plant when completed will produce 300 tons of coke per day, and will consist of a large double modern washer, beehive ovens with electrical road to the washer, a town of fifty good houses for the employes, a hotel capable of caring for seventy men, and the whole supplied with waterworks and sewerage system.

"A tunnel, some 600 feet long, develops the coal, which is transported by steam power from the tunnel to the washer, some 2000 feet distant."

PROGRESS IN FERGUS COUNTY.

Mr. E. W. King, of Chinook, writes that:

"While there have been no engineering features of any mag-

nitude in Fergus County during the past year, there has been a large amount of work done that will add very materially to the wealth and prosperity of this section.

"A system of waterworks has been installed in Lewistown, the county seat of Fergus County, and at this writing the water is just being turned into the mains. The supply is taken from Big Spring Creek and pumped to a large reservoir by water power, from which it is distributed throughout the city in wooden mains. The plant, when complete, will cost about $35,000, and has a capacity of 1,000,000 gallons per day.

"The Montana Railroad has let contracts for the extension of their line from Harlowton to Lewistown, a distance of 62 miles, and expect to have trains running into Lewistown by July 1, 1903.

"All of the property of the Great Northern Mining and Development Company, at Gilt Edge, has recently been transferred to the Gold Reef Mining Company, consisting of John A. Drake, John W. Gates and others of Chicago, and they are doing a large amount of new work. They have added two 80-horse-power boilers, a 10-drill compresser plant, laid a new 5-inch water line over 3 miles in length, built a new boarding and bunk house that will accommodate over 100 men, and have more than doubled the leaching capacity of the mill.

"They are also building a large roasting plant for treating the black or unoxidized ores that are becoming more plentiful as greater depth is gained in the mine.

"The owners of the Barns-King property at Kendall have doubled the capacity of their cyanide plant during the past summer, and have also purchased from the Anaconda Company a large hoisting engine with a self-dumping skip, which is now in successful operation.

"A corporation known as the Alder Gulch Mining Company has been organized during the past summer and are building a 100-ton cyanide plant in the Little Rockies, about five miles from Landusky. The lumber is all cut and the plant will be completed as soon as the weather will permit."

BUTTE CITY WATER COMPANY.

Of all our corporations, with the affairs of which I am in any way familiar, I think the Butte City Water Company has for some years past been by far the most extensively and unfairly advertised, in spite of the fact that during the greater part of that period the people have been furnished with better water than it is possible to obtain for a very large number of cities in the United States.

This has in a large measure been due to the fact that Butte has perpetually outgrown her available water supply, and to the further fact that the city appears to contain an unusual number of people that do not know good water when they see it.

Some years ago the company expended a large amount of money upon a masonry dam, with a view of storing the waters of Basin Creek, but the plan was modified when the dam had reached a height of 80 feet, as the stored water failed to keep, as had been anticipated.

In the year 1900 the company began the construction of a pumping station on the Big Hole River, some 20 miles from the city; a reservoir on Divide Creek at a sufficient elevation to cross the main range by gravity; a pressure main connecting the station and reservoir, and a hydraulic grade line from the reservoir on Divide Creek to their large storage reservoir above the city.

The foregoing is a very brief outline of the work described to you in a paper prepared by Mr. C. W. Paine and presented at our last annual meeting. The system was at that time doing modest work with a temporary pump, which had been installed till the larger one then under construction should arrive. A Nordberg pumping engine, designed especially for the service, has been in commission since, with very gratifying results.

A duty test was made upon this engine October 17, 1902, by Mr. G. M. Hutchinson, M.E., of Anaconda, the results of which have been summarized for your inspection by Mr. Eugene Carroll, the superintendent of the company.

On handing me this data Mr. Carroll remarks that the pump is giving most excellent satisfaction in service; that the test was extremely gratifying, and that the duty as determined by Mr. Hutchinson is believed to be, with one exception, the highest ever obtained from an engine doing this class of work. The exception noted was obtained upon a pump having a capacity of about 20,000,000 gallons in 24 hours, and recently erected by the Nordberg people at Pittsburg, Pa.

Date and Results of a Duty Trial of a Nordberg Pumping Engine for the Butte Water Company. Date of Trial, October 17, 1903.

TYPE OF ENGINE.

Horizontal, triple expansion, three crank, all cylinders jacketed on barrels and heads, reheating receivers. Jet condenser and two vertical single-acting air pumps, 17″ diameter by 19½″ stroke, driven from connecting rod of low pressure engine, with two other boiler feed pumps and two jacket drain pumps attached.

DIMENSIONS OF MAIN ENGINE AND PUMPS.

	H. P. Cyl.	I. P. Cyl.	L. P. Cyl.
Diameter of cylinder, inches	24	44	62
Stroke of piston and pump plunger, feet	4⅓	4⅓	4⅓
Diameter of piston rod, inches	5⅞	5⅞	5⅞
Average clearance computed from drawing, per cent.	3.25	2.80	2.30
Ratio of volume of cylinder to H. P. cylinder	1.00	3.51	7.03

DIMENSIONS OF MAIN ENGINE AND PUMP.

	H. P. Cyl.	I. P. Cyl.	L. P. Cyl.
Horse power constant for one pound M. E. P. and one R. P. M.	.055845	.1961	.39289
Number of water plungers, double acting		3	
Diameter of plungers, inches		11.25	
Diameter of piston rods and tail rods of water cylinders, inches		7	
Net area of plungers, square inch		60.917	

TOTAL QUANTITIES, TIME, ETC.

Duration of test, hours	12.09
Total water fed to boiler, pounds	96,528
Water caught by separator, plus that used by calorimeter, pounds	3,650
Water lost by leakage of boiler and piping, pounds	1,448
Total wet steam consumed by engine, pounds	91,430
Moisture in steam near throttle, per cent	1.23
Total dry steam consumed by engine, pounds	90,305
Total wet steam consumed per hour, pounds	7,562
Total dry steam consumed per hour, pounds	7,469

PRESSURES AND TEMPERATURES.

Pressure in steam pipe, near throttle by gauge, pounds per sq. in.	144.4
Barometric pressure, inches of mercury	24.5
Pressure in first receiver by gauge, pounds per sq. in	22.0
Pressure in second receiver by gauge, pounds per sq. in	1.3
Vacuum in condenser, inches of mercury	19.9
Pressure in low pressure jacket by gauge, pounds per sq. in	40.6
Temperature of feed water during duty test, degrees Fahr	46.81
Temperature of feed water during temperature test, degrees Fahr.	127.77
Temperature of injection water during temperature test, degrees Fahr.	44.06
Pressure indicated by gauge on force main air chamber, pounds per sq. in	357.51
Vacuum indicated by gauge on suction air chamber, inches of mercury	5.49
Pressure corresponding to vacuum given in preceding line, pounds per sq. in	2.69
Vertical distance between water levels in the two air chambers, feet.	10.33
Pressure equivalent to distance between water levels in the two chambers, pounds per sq. in	4.48
Total pressure pumped against, pounds per sq. in	364.68

SPEED AND POWER.

Total number of revolutions	25,312
Revolutions per minute	34.897

	H. P. Cyl. Head	H. P. Cyl. Crank.	I. P. Cyl. Head	I. P. Cyl. Crank.	L. P. Cyl. Head	L. P. Cyl. Crank.
M. E. P. pounds, per sq. in....	49.69	48.77	14.61	15.04	9.05	9.16
Indicated horse power	96.8	95	100	102.9	124	125.5
Indicated horse power for cylinder		191.8		202.9		249.5
Total indicated horse power...				644.2		
Horse power of pump cylinders				610.8		

STANDARD EFFICIENCY AND OTHER RESULTS.

Heat units consumed by engine per indicated horse power per hour, B. T. U	12,787
Heat units consumed by engine per indicated horse power per minute, B. T. U	213
Wet steam consumed per indicated horse power per hour in cylinders, jackets and receivers, pounds	11.74
Dry steam consumed per indicated horse power per hour in cylinders, jackets and receivers, pounds	11.59
Steam accounted for by indicator per indicated horse power per hour, near release in low pressure cylinder, pounds	10.15
Number of gallons of water pumped in twenty-four hours by plunger displacement, gallons	4,134,200
Friction of engine and pump, per cent	5.19

DUTY.

Duty per million British thermal units used by engine, foot pounds	146,800,000
Duty per thousand pounds of dry steam used by engine, foot pounds	161,870,000

THE NORTHERN PACIFIC.

The Northern Pacific Railway Company have accomplished much within the year in the way of betterments upon their lines in Montana, consisting of the elimination of curves, the reduction of grades, the filling of numerous trestles, the replacing of wooden bridges with steel structures and the equipment of many miles of the main line with 72-pound steel rails.

Items of this expenditure which are of special interest, and features upon which we may happily congratulate those who, at the present moment, are extending such hospitable entertainment, are the revision of the freight yard, the new brick car shops and the new passenger depot at this point.

I am indebted to W. L. Darling, chief engineer of St. Paul, who, under date of December 19th, furnishes the following statement of his company's expenditures in Montana for the year 1902:

YELLOWSTONE DIVISION.

Third district, lowering cuts and raising sags	$11,805.89	
Third and Fourth districts, twelve dykes to protect embankment along Yellowstone River	12,601.48	
Bridge work, permanent work exclusive of repairs	24,467.03	
Bull Mountain change of line	74,013.14	
		$122,887.54

MONTANA DIVISION.

45.25 miles new 72-pound steel	$76,468.73	
Concrete arch culverts	10,130.43	
Billings, five-stall addition to round house	8,740.66	
Livingston, new machine shop, power plant and change in old	64,940.94	
Livingston, track changes in yard, account new passenger station	23,492.89	
Erection No. 9 copper wire, 335.4 miles	14,700.04	
		198,473.69

ROCKY MOUNTAIN DIVISION.

New 72-pound steel, 30 miles	$62,719.09	
Bridge work, permanent	26,547.21	
Missoula, new brick car shop	21,139.98	
Missoula, new passenger depot	21,069.15	
Channel changes	46,858.42	
Cœur d'Alene line, retaining wall renewals	13,925.19	
Bearmouth, change of line	14,339.97	
Bridge work	4,471.89	
Helena, rearrangement of freight tracks	5,468.04	
Missoula, revision of freight yard	12,334.88	
		228,873.82
Total		$550,235.05

THE GREAT NORTHERN.

E. R. McNeill, resident engineer, with headquarters at Havre, whose district extends from Minot, N. D., to Bonner's Ferry, in Idaho, and covers 836 miles of the Great Northern Railway, writes that during the year 1902 the following betterments have been made:

One hundred and twenty-two miles of track have been relaid with 77½-pound steel, replacing old 60 and 68-pound rails.

Thirty-five bridges have been filled, replacing two-thirds of a mile of timber structure.

Five bridges, requiring 700 tons of structural steel and replacing one-third of a mile of timber tresseling and under construction with foundations for the work, containing 3000 yards of concrete masonry, practically completed, and under contract for delivery in May, 1903.

Ten thousand cubic yards of concrete masonry has been placed in culverts on the line.

Between Williston, N. D., and Glasgow, Mont., nine new water supply stations have been put in, involving the construction of two large reservoirs to impound flood waters and five settling basins, to be used for clarifying the muddy water which is pumped from the Milk and Missouri Rivers. This settlings basin plan involves two pumpings of the water, but gives us a much better quality and practically does away with the annoying nuisance of mud-burned locomotives.

In connection with the reservoirs and basins, complete new tanks, pipe lines, windmills and gasoline pumping plants have been installed. The cost of all the above enumerated improvements has been in the neighborhood of $600,000.00.

During 1902 the branch line from Jennings, Mont., to the Crow's Nest Mines, at Marussey, B. C., was completed and put in operation. This line, which is 94.46 miles in length, 42.74 miles being in Montana and 51.72 miles in British Columbia, was started early in 1901, and I believe some mention was made of this in our President's address one year ago.

I am unable to give you any accurate information as to other portions of the Great Northern, but understand the Western district from Bonner's Ferry to the coast has done a large amount of work in filling bridges and erecting permanent steel structures to replace many of their timber trestles. During the year the Great Falls and Canada has changed from narrow to standard gauge, and is now being operated by that company under the supervision of the resident engineer of the Montana Central, with headquarters at Great Falls.

Information of the details of this organization did not reach me in time to communicate with the officers at Great Falls, and the following item of unusual interest regarding a timber structure on this line is abstracted from an article in the *Anaconda Standard* under date of December 14, 1902.

The bridge, which is one of the largest timber trestles in the Northwest, is located on the Teton River, about 44 miles from Great Falls; is 2333 feet in length and has a height of 110 feet above the mean water in the river. It is intended to accommodate the heaviest track, Great Northern engines of the 168-ton class, the timbers used being from 25 to 35 per cent. heavier and the members designed to support from 40 to 60 per cent. larger loads than structures built for such service some four or five years ago.

The bents are spaced 20 feet from center to center and contain six 12 x 12-inch posts, while the floor system consists of eight 10 x 20-inch stringers 40 feet long. Of the total length as above

given, 150 feet consist of a deck Howe truss span, the upper and lower chords of which are composed of four 9 x 18-inch timbers 74 feet in length. About 800 piles were driven in the foundation for this work, while 2,300,000 feet of Washington fir was used in its construction.

About one mile further north on the same line is another bridge, 903 feet in length, crossing the Muddy River at a height of 105 feet above high water, with a Howe truss span 120 feet in length, and in the construction of which about 700,000 feet of lumber were used.

The problem of obtaining a satisfactory water supply is one which is frequently presented for solution along the low, sluggish streams that traverse our northern border, while in many localities the engineer is confronted with the more serious question of obtaining a supply of any kind.

While at Havre last October I was interested in examining two plants, one at Fort Assinoboine, which has been in operation for several years past, and another recently placed in commission for supplying the shops of the Great Northern Railroad at that point. A light grade, with small surface discharge, strongly alkaline during the low-water season, is a characteristic of Milk River and other streams in this vicinity, but another feature, quite pronounced in many places, is that there is a large sub-surface flow of much better water, coming, probably, from the hills some miles away.

The plan adopted to secure a supply from the sub-flow may not be altogether new, as it is a collective application of what is called the drive well, but I am quite surprised to see it in use in this State, and trust a brief description may be of interest in this connection.

The points, whose character differs somewhat with the nature of the material through which it is to be driven, are attached to the end of a 2-inch pipe and driven upon each side of a 10-inch horizontal pipe known as the header, one end of which is closed and the other attached to the suction end of the service pump.

The spacing used by Mr. Brader, who drove the wells of which I am speaking, was 4 feet between connections, with the points driven 4 feet from and on alternate sides of the central line of the draft pipe or header above mentioned.

This description locates the points at approximately 8 feet between centers, and the number driven is determined by the quantity of water required. Each point is tested as driven and adjusted and cleaned until a satisfactory flow is obtained, and

when all are in working order they are connected to the header and the pump is started.

Forty-five points were driven for the Great Northern shops, of which but forty were at that time connected.

The regular demand upon this well was estimated at about 200,000 gallons per day, but I was informed that on a test run lasting several days water had been drawn from this well at the rate of 400,000 gallons in 24 hours, without exhausting the supply.

The well at the Fort contains about the same number of points, and has given excellent satisfaction for several years past, though the demand upon it has not been as great as is now being made upon the one at Havre.

Among the recent commissions of unusual interest I will mention the power and transmission plant of the Missouri River Power Company, whose wheels and dynamos are located at Canyon Ferry, with a line extending to Butte, over which they are sending current for commercial distribution at a pressure of 50,000 volts.

As Mr. M. H. Gerry, Jr., the general manager, has consented to present the Society with some notes regarding the work as soon as the time at his disposal will permit, I pass the subject without further remark than to observe that when the horse power is transmitted, the number of miles covered and the voltage used upon the line are all considered, this enterprise becomes one of the largest undertakings now in successful operation.

I am quite sure the members present will unanimously concur in the opinion that the plant of the Missoula Water Company, which we have recently had the pleasure of inspecting, is one of the most complete and serviceable of its kind, and goes far toward assuring the prosperity of the community it is intended to serve.

On this subject our fellow-member, Mr. C. W. Paine, the engineer in charge, writes as follows:

"The work which has been done during the past season by the Missoula Water Company was rendered necessary by the decay of the old flume line, which has been in use since 1887, and by the demand for increased pressure in the mains of the company. The new work consists in, first, a diverting dam in the Rattlesnake Creek about four miles above the city, a pipe line extending from the dam to a point near the old reservoir and a new reservoir at the lower end of the pipe line. The dam is a rock-filled timber-cribbed structure, designed simply as a diverting dam. It is about 6 feet in height above the foundation and 63 feet in width of spill-way. It rests upon bed rock almost entirely, to which it is anchored by suitable drift bolts. The timbers are 12 x 12 fir, spaced from 4

to 7 feet on centers. The abutments are also rock-filled timber cribs. The west abutment is anchored to the rocky cliff on that side of the stream. From the east abutment a dyke of earth has been thrown up, extending to the higher ground about 200 feet away. A cut-off wall of concrete was built at the upper toe of the dam and dyke The water is taken from the stream above the dam through a submerged crib of timber into a tunnel through the rock 70 feet in length, and at the lower end of the tunnel it is connected by means of concrete to the wooden pipe. A gate is placed at the upper end of tunnel; also a screen. The timber crib also acts as a screen in keeping out the coarser floating material in the stream. The wooden pipe is built of California redwood, having a finished thickness of 1½ inches. It is banded with ½-inch round steel bands. The pipe is laid on a grade of 0.71 per 100 feet, giving a capacity of about 30,000,000 gallons daily. A weir and screen chamber is built a short distance below the dam, where a 30-inch gate valve is placed and set of double screens and a weir for measuring flow. The pipe is generally laid on a uniform grade, but this has been departed from, however, in crossing several ravines and wherever the necessities of the work seemed to demand it. The usual air valves and blow-offs are placed on the line. Midway between the dam and the reservoir a chamber of masonry is built, containing a 30-inch automatic float valve set in the line, which, in connection with a similar valve at the reservoir, operates to automatically keep the lines full of water at all times and to supply the demands upon it. The reservoir is circular in plan, 106½ feet in diameter, and designed to carry 15 feet of water. The walls are of concrete, 2 feet in thickness, and the bottom is also of concrete and is 1 foot in thickness. The pipe around the reservoir is so arranged that the reservoir can be cut out of service and the city supplied directly from the pipe line. Under the old system the pressure in the business center of town was about 65 pounds per square inch. The new reservoir gives 80 pounds, which can be increased to 100 pounds, if desired, by cutting out the reservoir and taking the supply directly from the pipe line."

The foregoing comprises all of interest that I have been able to gather of our progress within the State.

From the numberless undertakings beyond our boundaries I have selected power transmission and wireless work as topics of special interest, and have compiled from current publications a few items regarding our recent achievements and progress along these lines.

NOTES ON RECENT ELECTRICAL WORKS.

LONG DISTANCE TRANSMISSION.

The world has probably never experienced such a complete change in mechanical appliances, nor undertaken such a rapid and general readjustment of invested capital, as that which has followed the introduction of electricity for the transmission of power.

We hear much of "electric power," and to many the term seems to convey an idea of some recently discovered source of energy, some force that is in competition with steam and water as a source of kinetic manifestations. Our language does not seem to contain the word I desire to express the distinction I am about to make, and as engineers I think we often use the term carelessly and fail to discriminate between the power and its transmission.

As a matter of fact, electricity is rarely a prime mover, though it may be, and sometimes is, for when a piece of zinc is burned in a battery it is as truly a prime source of energy as when coal is burned under a boiler; but note, if you please, how small a proportion of the current utilized to-day is derived from such a source.

Select any of the electrical manifestations about us and follow the wires back. They may lead us to the Big Hole, to the Madison, to the Missouri, to Bonner or to some of the many steam plants now in service, but they will, with rare exceptions, lead us to one of these prime sources of energy.

In fact, there is no "electric power" now being used that is worthy of notice when we divest the term of its popular meaning, give the phrase a literal definition and restrict its application within the limits required in technical controversies.

If the conditions of electrical manifestations be closely analyzed, we see that the electrical current is not a source of energy, but a pliant and reliable means for its instantaneous transmission.

During the earlier years of my life in this State I was engaged in mechanical work, consisting largely in the setting and running of machinery. This was before the days of dynamos and transformers, and, when a problem for the transmission of power was up for solution, we considered the revolving shaft, a running belt or a reciprocating rod for the shortest transmissions; and for longer distances we had recourse to a running wire rope or a pressure pipe line, with a choice of water, steam or compressed air, all with their attendant annoyances under the varying conditions, and all with losses so great that distance very soon prevented the adoption of either.

Do you appreciate that the electric current, as we apply it to-day, is accomplishing no more than the shaft, the belt, the rope-

drive or pipe line accomplished over the limited distances we were then able to cover; that its relation to power and work coincides exactly with the position occupied by any and all of the mechanical agencies just named?

We see, then, that the electric current is nothing more than a means for transmitting energy; but, as an agent for this purpose, how incomparably superior do we find it to any of the antiquated appliances of twenty-five years ago.

No better evidence of its great superiority for even short transmissions is needed than to observe how rapidly it is replacing belts and countershafts, even where the change has necessitated the scrapping of much costly and otherwise efficient machinery.

But the consignment of revolving shafts and running belts to the scrap heap is of trifling consequence when compared with other features of its mission in modern economies. It transmits our largest units of energy for miles, instead of feet or yards, and accomplishes it with surprising efficiency.

Not many years since, in my cock-sureness on mechanical subjects, I certainly would have ridiculed a proposition to conduct a thousand horse power over a wire not larger than a pipestem; and this frame of mind often recurs to me as I pass under the pole lines that are girdling the country so rapidly, and reflect that the slender aerial threads are actually conveying the energy of several thousand horses, transmitting it for many miles, instantly, noiselessly and with no apparent motion.

My present practice differs greatly from my early training, but it is a fair measure of our advance along this line. During the twenty years just passed we have wrought wonderfully in the distribution of power. Much has been accomplished within the last year, and it is quite certain that much more will be done in the years to come, but to me it appears quite evident that our future progress will be slow as compared with that of the past.

In our professional endeavors we are limited by the weight, buoyancy and strength of our material, by friction, deterioration, climatic conditions and a thousand unnamed features that always circumscribe our field of successful effort. Some late experimental work in the line of electrical transmission furnished unwelcome evidence that the ultimate limits are being approached; that as voltage is raised, our insulation is breaking down, and that, upon lines constructed with strict regard to the details of approved practice, serious losses are found to occur.

No field of mechanical effort has been studied with greater care than the one which embraces the science of applied electricity,

as in this it has been possible to measure the forces with greater precision, to trace the losses accurately, and thus apply a fund of technical knowledge that has not been available in other fields to solve the problems involved.

An accurate measure of the energy lost is often half of the battle toward its prevention, and to our ability to detect the slightest leak in an electric circuit do we owe the present achieved perfection in the manufacture of electrical machinery.

Standard shops will now build electrical apparatus and guarantee an efficiency performance that cannot be approached by the makers of steam or hydraulic machinery.

I regard the opportunity for possible improvement in the manufacture of motors and dynamos as far smaller than are the chances to improve in the manufacture of steam engines, to say nothing of water-wheels, pumps and many mechanical appliances in which the losses are known to be exceedingly large.

Of course, much remains to be done on the line of improved insulation, which will enable us to carry a higher voltage; much in securing a better proportion of parts; large improvement may result from the use of finer material, and much yet be gained in the application of closer workmanship. All of these features and others not named will gradually raise the efficiency of our electrical machines, and may considerably extend the length of our circuits, but a measurement of the steps by which our recent advance along this line has been attained compels me to regard our race in long-distance transmission as well nigh run.

I do not pretend that it is impractical to cover a much greater distance than has yet been attempted, or that it is impossible to insulate for a far higher voltage than has yet been employed, but for commercial service we must remember that it is seldom a question of what it is possible for us to do, and that the solution of the problems presented always turn upon what we find it profitable to accomplish.

As with moderate pressure, the cost of copper sufficient to prevent a wasteful loss upon the line, already limits the length of our circuits and confines our profitable transmissions within comparatively narrow bounds, so the cost of transforming to a very high voltage, and after transmission the cost of reducing these currents to serviceable commercial pressures, together with the cost of proper insulation for these high tension currents to avoid serious losses, all combine to limit our radius of profitable transmission.

Of course, different conditions will prevail as each successive

undertaking is considered, and other elements will become involved, some of which may, in special cases, go far toward extending our limits in this field; but I am persuaded that this apparently necessary accumulation of capital, this constant pressure of fixed charges, is placing an embargo of cost per horse power upon many undertakings now in hand, and circumscribes every such enterprise with bounds beyond which it is impossible to go in the field of commercial transmission.

True, there is always a possibility of some new discovery or some new application of an old and well-established principle, and the so-called scientific reporter for the daily press is forever pointing in that direction, while the expectant reader watches with unshaken faith for the next miraculous manifestation; but the practical electrician finds nothing of value and but little of interest in discoveries that are to be perfected in the near *future* and presented to an astonished public *very soon.*

Before closing this paper I will present the results of some recent experiments in a field of wondrous possibilities that is now opening before us; but, with this in full view, I have expressed myself as believing that we are rapidly approaching the limits in transmission, and wish to call your attention to the fact that our technical knowledge on this subject is very great; that our theories seem to cover the entire field with reasonable consistency, and that, in practice, within the bounds apparently fixed by natural laws, we have this most elusive and capricious manifestation of kinetic energy under perfect control. In short, I do not concur in the popular estimate that "electricity is still in its infancy."

WIRELESS TRANSMISSION.

The art of transmitting a message without wires is not entirely new, and some of you will doubtless recall a series of successful experiments, undertaken some five or six years ago, in which messages were sent from and received upon a moving train. The well-known property of electrical induction was employed in that work, the instruments in one electrical circuit being worked by the induced current set up by the flow of electricity in another circuit in the immediate neighborhood. About 100 feet was the maximum distance between circuits, if I remember correctly, while 20 or 30 feet was the practical limit under all conditions.

Prior to the recent development of the Hertzian wave, electrical currents possessing many peculiar properties and many ingenious mechanical contrivances have been tested in efforts to transmit messages without wires, and, though moderately successful in many instances, none of these experimenters appear to have reached

far enough to give their apparatus any practical or commercial value.

Within the past five years several very able investigators, with large amounts of money at command, have been experimenting with electro-magnetic waves, and the advance along this line has been truly phenomenal.

An appeal to the courts will doubtless be required to determine the value of rival claims, the priority of inventions, the validity of patents and the intricate phases of infringements, etc., but in the meantime Marconi's name has, in this country, at least, become inseparably connected with the art of wireless telegraphy. Extended details of the apparatus used have not been made public; reliable statements of what has been accomplished are not often made. I make no pretense of possessing more than a superficial knowledge of the subject, and I feel that I presume very largely upon your patience when I attempt to bring the matter before you.

I have, however, for some years past, noted with interest the progress being made, and I hope that the recent announcement that messages have actually been transmitted across the Atlantic Ocean without wire connection may make this brief and non-professional description of some of the apparatus and methods employed of some interest to you.

All successful efforts at long-distance transmission have employed the "Hertzian or Electro-Magnetic Wave." These waves differ from the electric current, but I shall pass all theories and speculations regarding this difference and endeavor to give you a general idea of the arrangements of the electrical circuits in producing and receiving them, and some of the apparatus by which they are again transformed into electric circuits that give an intelligible signal.

You are probably all familiar with the Leyden jar, and will recall the apparent spark which usually accompanies the discharge of what we call a condenser. You may remember, too, that some years ago we were informed that the apparent spark was in reality a succession of sparks, and that the current actually surged back and forth across the air gap many times during the discharge; in fact, a descriptive term has attached, and the spark is known as the "disruptive discharge."

The frequency of the oscillations depends upon the ratio of the co-efficients of inductance, capacity and resistance within the circuits, and is increased as the potential of the charging current is raised.

This circuit, containing the air gap, is called an oscillator, and

Professor Thompson makes the astounding statement that, upon a circuit of atomic size, the current would oscillate trillions of times per second. Of such a condition, which is wholly theoretical, of course, we have no fair conception, as it touches the margins of belief and tests to the utmost our faith in a theory that seems to approach the miraculous, but it serves to prepare us in a measure for the sober statements that follow of the hundreds of thousands of times that a high potential current is known to oscillate across an air gap, of the electro-magnetic waves thus emitted, whose length can be determined and the persistence of which is sufficient to cross the ocean.

An astonishing variety of appliance, connected in every conceivable manner and worked under every imaginable condition, appears to have been used by the various experimenters in this field; but through the apparatus used in all successful work it is possible to trace three distinct yet interdependent electrical circuits.

In Figs. 1 to 5, inclusive, I have attempted to reproduce portions of the apparatus used. My illustrations are not intended to represent the appliance now in service; they are in a large measure diagrammatic in character, and are presented with a view of showing the relations and manner of connecting the three circuits just mentioned, and with the hope that they may assist you in following the current in its various transformations through these circuits.

Referring now to Fig. 1, the battery (6) or source of current, with the key (7) for arbitrarily making and breaking contact, are connected with the primary winding of a Ruhmkorff coil (4) to form the first circuit (A), in which is inserted an ordinary automatic circuit breaker (5). The secondary winding of the coil (4) is connected to the opposite sides of the oscillator containing the air gap, and forms the second independent circuit (B), which serves to charge the third circuit with an interrupted current of moderate frequency, but of very high potential. The third independent circuit (C) contains the air gap (2), usually arranged between two polished spheres immersed in oil, between which the disruptive discharge takes place and across which the current oscillates with enormous frequency and potential.

Capacity areas are usually introduced in this circuit to control, in a measure, the frequency of the oscillations across the air gap. One side of this circuit is usually, though not of necessity, carried to ground (3), while the other is connected to the antenna (1), from which the electro-magnetic oscillations or waves are emitted with sufficient persistence to cross the Atlantic.

It is explained that on closing the key (7) on the first circuit, the battery (6) sends a strong low-potential current into the primary of the coil (4); that this current is broken as rapidly as it

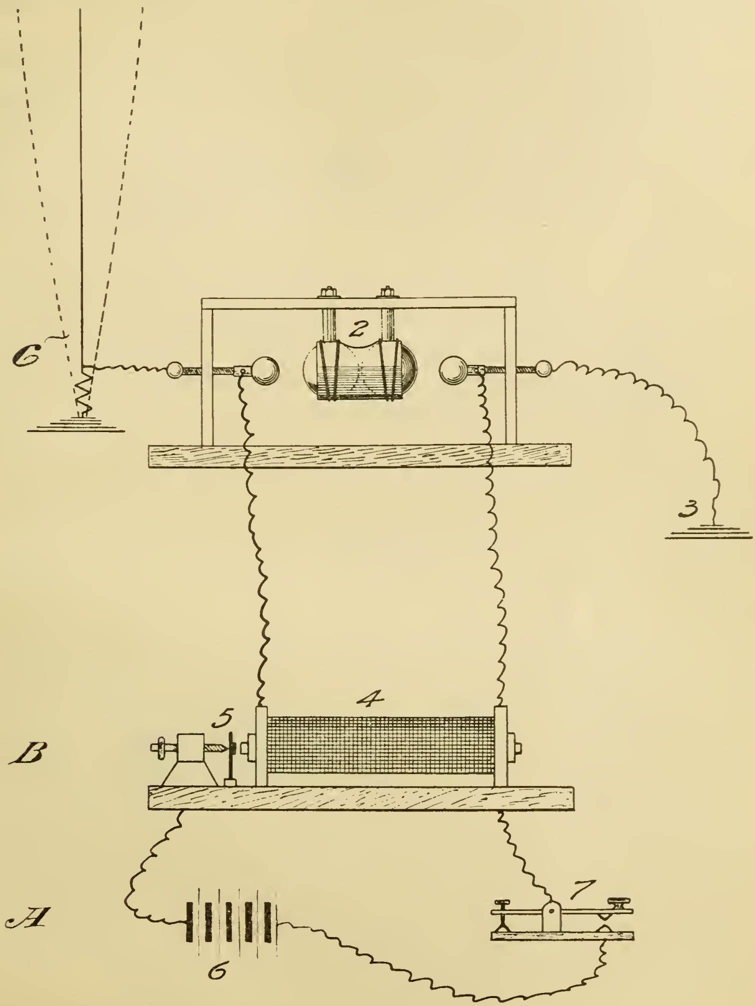


Fig. 1.

is closed by the interrupter (5), thus inducing in the secondary a high-potential current of moderate frequency, with which the oscillator is charged; that this charge surges across the air gap (2) with marvelous frequency,. producing in the antenna (1), from

which the free waves are emitted, oscillations of high potential and high frequency. It is further stated that these emitted waves are in many ways analogous to those of light; they travel with the same velocity, are polarized, reflected, refracted and in many ways are handled as are the rays of light.

The mechanism for receiving is largely the counterpart of that used in sending; in fact, every description of the station apparatus that I have yet seen shows the last circuit used in transmission as identical with the first used in receiving; that is, the wires rising from and forming part of this circuit from which the waves are emitted are the wires upon which the waves from other stations are received.

Beyond the first circuit, however, the receiving apparatus differentiates rapidly, and one is soon bewildered by the intricate complications of circuits that are employed, and the great variety of apparatus that has been used more or less successfully by the various experimenters in detecting these electro-magnetic waves.

Somewhere in the circuit is usually placed a coherer, in which silver filings, granulated carbon and other substances have all been used with success. It has been used in many forms of varying proportions and of different degrees of sensitiveness. For description here I select one used by Mr. Marconi with gratifying results.

In Fig. 2, which is largely diagrammatic, I show the apparatus and connections used at the receiving station for intercepting the electro-magnetic waves and obtaining an intelligible Morse signal.

The vital element in this arrangement, the "coherer," shown at (2) in Fig. 2, and upon an enlarged scale in Fig. 4, consists of a small glass tube, in which are inserted two silver plugs (3), to each of which is attached a leading-in wire (1) for connecting with the other elements of the circuit, one being led to the antenna when a message is to be received. Between these two silver plugs a space (2) of about one-fourth of an inch is left, and this space is filled with a mixture of 96 per cent. nickel, 4 per cent. of silver finely granulated and a trace of mercury.

The tube is then exhausted to 1-1000 of an atmosphere and hermetically sealed through the Y-shaped excrescence (4), which destroys its otherwise symmetrical appearance.

The virtue of this element resides in the granulated particles inclosed between the silver plugs, which ordinarily offer a strong resistance to the passage of an electrical current.

These particles are remarkably sensitive to electro-magnetic waves and other electrical disturbances, becoming polarized under

the influence; in other words, they cohere, and the granulated mass at once becomes an excellent conductor.

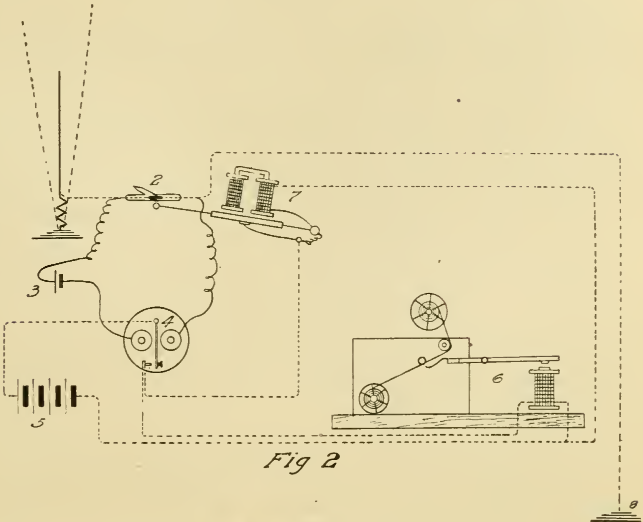


Fig 2

Fig 4

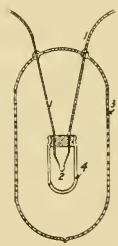


Fig 5

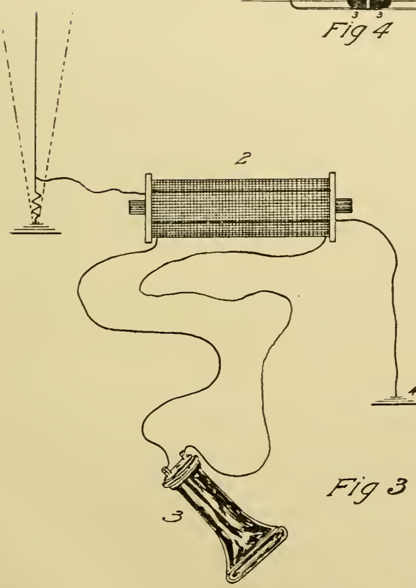


Fig 3

This property of the coherer, or detecter, as it is sometimes called, (2) in Fig. 2, is utilized by connecting a local circuit containing a relay (4) and a single cell (3) to its opposite terminals. Normally no current flows, as the local cell is too weak to

break down the resistance offered by the granulated mass, and the circuit remains broken across the gap.

On the receipt of a message, however, the Hertzian wave emitted by the oscillator at the sending station causes oscillations to occur in the antenna (1) at the receiving station, which are strong enough to break down the resistance among the particles; they cohere and form an electric bridge across the gap (2), over which the local circuit at once crosses and actuates the relay (4). As all operators and electrical men well know, the translation from an active relay arm to the Morse sounder or printing point is one of detail only, and all the requirements are thoroughly understood.

I show diagrammatically one method successfully used by Marconi for accomplishing this, and for working, at the same time, and from the same relay that is used to actuate the sounder, a mechanical tapper whose office it is to jar the inclosed granules, causing them to de-cohere.

A battery (5), Fig. 2, is connected, through the relay (4), with the magnet (6) for working the Morse printing arm, and the magnet (7) for actuating the arm that taps the coherer.

Normally this mechanism is all quiescent, but on the arrival of waves from the transmitting station, which break down the resistance in the coherer (2), current from the local battery (3) closes the relay (4), when the battery (5) sends a current through the magnet (6), depressing the printing arm, and a current through the magnet (7), causing the armature to vibrate and tap the coherer, under which the particles "de-cohere" as soon as the waves cease to arrive, thus introducing resistance and breaking the local circuit, at which everything again assumes its normal condition.

From many appliances that have been used in lieu of the Morse sounder for manifesting the presence of electro-magnetic waves, I select for illustration a telephone receiver and a miniature flashlight.

Fig. 3 shows diagrammatically the manner of connecting a telephone receiver (3) with the secondary of a coil (2), the primary of which is wound around a soft iron core and connected in a circuit between the antenna (1) and the ground (4).

The Hertzian rays pass through the primary, inducing in the secondary a current which actuates the diaphragm in the receiver, producing a note that is clearly audible. A revolving magnet is used in connection with this receiver, but, as it is shown detached, and as I have not been able to learn how it is mounted, I can only say that it is in some way made to affect the magnetism of the iron core, which in turn affects the character of the induced current

passing to the receiver. A tiny lamp (see Fig. 5) has also been used for detecting the presence of electro-magnetic waves without the aid of a coherer. The manufacture of this lamp appears as a triumph of delicate workmanship, so interesting, in fact, that I copy a brief description from a late number of the *Engineering Magazine.*

The lamp is constructed with a short loop of silver, having a diameter of 2-1000 of an inch, drawn with a core of platinum, having a diameter of 6-10,000 of an inch fastened to the leading-in wires (1), these in turn being sealed in a glass bulb (3).

The tip of the silver loop (2) is dissolved by nitric acid, leaving the platinum wire exposed, and to decrease the loss of heat by radiation the loop is inclosed in a silver shell (4).

Details of station construction are not easily obtained, but from a late issue of the daily press I abstract the following interesting description of one recently installed at Cape Cod:

"Four wooden towers, 28 feet square at the base and 12 feet on top, are erected to a height of 215 feet at the corners of a rectangle, each side of which has a length of 210 feet. These towers are securely anchored and cross-braced with wire rope, and from the top of each to the next are drawn wire cables, forming a rectangular bridge from tower to tower. From each of the four horizontal bridges thus formed are suspended fifty copper cables, composed of seven strands $\frac{1}{8}$ inch in diameter, tightly twisted together, making 350 separate wires upon each side of the station, or a total of 1400 in all."

From this it appears that the solitary vertical wire, known as the antenna of the original experiments, has been very greatly multiplied.

It is stated that this height of station will generate a wave length of about 860 feet, which corresponds to a frequency of 1,100,000 oscillations per second.

Current to charge the oscillator is furnished by a 40-horse-power alternating dynamo under pressure of 2000 volts, which is raised by transformers to a pressure of 20,000, and still further increased, by means of condensers, to a pressure of from 50,000 to 70,000 volts.

It is claimed that secrecy can be obtained by "tuning the station," which is accomplished by introducing or cutting out resistance or capacity in the oscillating circuit, thus making it "resonant" or in tune to respond to waves of a predetermined length, while rejecting or remaining passive to the impact of all waves that do not oscillate with the pre-arranged frequency.

I do not think it yet possible to determine what can be accomplished along this line, but it appears evident that the future of wireless work as a commercial factor depends in large measure upon the success attending the efforts now being made to obtain a selective and secret service.

I have endeavored to describe a few of the many appliances which have been successfully used in sending and receiving messages without wires, and trust you have been able to follow me through the mechanical manipulations and visible manifestations involved.

Beyond this it is impossible to proceed very far, for we find a great gulf fixed, and the men who are making these subjects a life-study would tell us that we have followed them to the very brink. They tell us of wave lengths that range from the fraction of an inch to thousands of miles, of vibrations that are numbered in millions and billions and trillions per second, of velocities so amazingly great and of atoms so infinitely small that our conception becomes bewildered and our comprehension utterly fails.

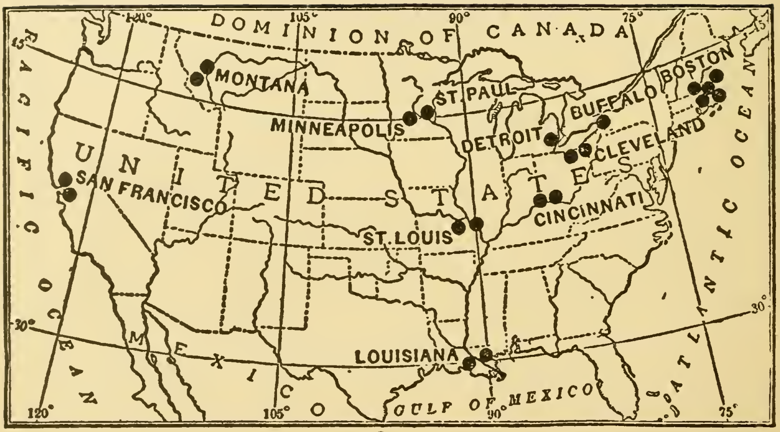
Wave lengths, oscillations and vibrations are probably as serviceable as other terms would be in impressing us with a condition of which the finite mind can have no fair conception, but when we see these men proportioning resistance, inductance and capacity, and tuning their stations to receive one message and reject all others, we are compelled to recognize a practical result and must conclude that there is something tangible in their speculations.

When the discharge of a condenser in England is heard in America, when a battery on the coast of Cornwall will flash a light on the banks of Nova Scotia, when the pressing of a key at Poldhu works a sounder at Glace Bay, when these things are done within the second and without other connection than the earth beneath, the ocean between, the air around and the sky above, then we are face to face with a practical result which appears to possess wonderful possibilities.

It is still too early to measure the commercial value of this work, and conservative observers do not regard it as likely to disturb existing investments to any great extent, but, if successful, anticipate its filling a new and heretofore unoccupied field among the world's industrial enterprises.

To me the most significant feature of this achievement lies in the practical utilization of those intense and infinitestimal vibrations or waves, as they are termed, engendered in that elastic, imponderable, elusive medium which we call the ether and which we imagine as permeating all things mundane and filling space beyond.

In the face of this achievement, may we not indulge the hope that we may yet be able to propagate and distribute vibrations of still higher potentials and frequency; that we may obtain light without heat; that we may be able to intercept and transform the yet more intense vibrations that are constantly bringing to us from the sun all that we have of power and motion, all that we experience of change and growth, all that we know of warmth and comfort; in fact, all that we know of life, which is so mysteriously conveyed to us upon wings of light?


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
LOUISIANA
GULF OF MEXICO
120°
105°
90°
75°
45°
30°

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BOSTON FOUNDATIONS.

BY JOSEPH R. WORCESTER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, January 28, 1903.*]

IN preparing the following paper the writer has a desire, at the outset, to impress upon his hearers the fact that he is venturing upon a subject which he is wholly incompetent to deal with in a didactic manner. During his practice he has been struggling to acquire information as to foundations in every way possible, which means, generally, by asking questions from other engineers who have learned by experience, and he realizes that many of the members of the Boston Society of Civil Engineers, who have with the utmost liberality answered his inquiries, are vastly better fitted to deal with the subject than the present writer. If, however, they cannot be prevailed upon to make the first move, it is the writer's earnest hope that they will set him straight if he expresses any wrong opinions, and will co-operate in bringing out the subject in its various aspects by joining in the discussion.

No attempt will be made to enlarge the subject so as to comprehend foundations of characters different from those met with in this immediate vicinity; and this restriction narrows our scope very decidedly; for many conditions, such as those encountered in New York and Chicago, for instance, are entirely wanting in Boston proper. Moreover, to further limit our investigation, we will confine ourselves chiefly to foundations for ordinary structures not requiring excessively large foundations.

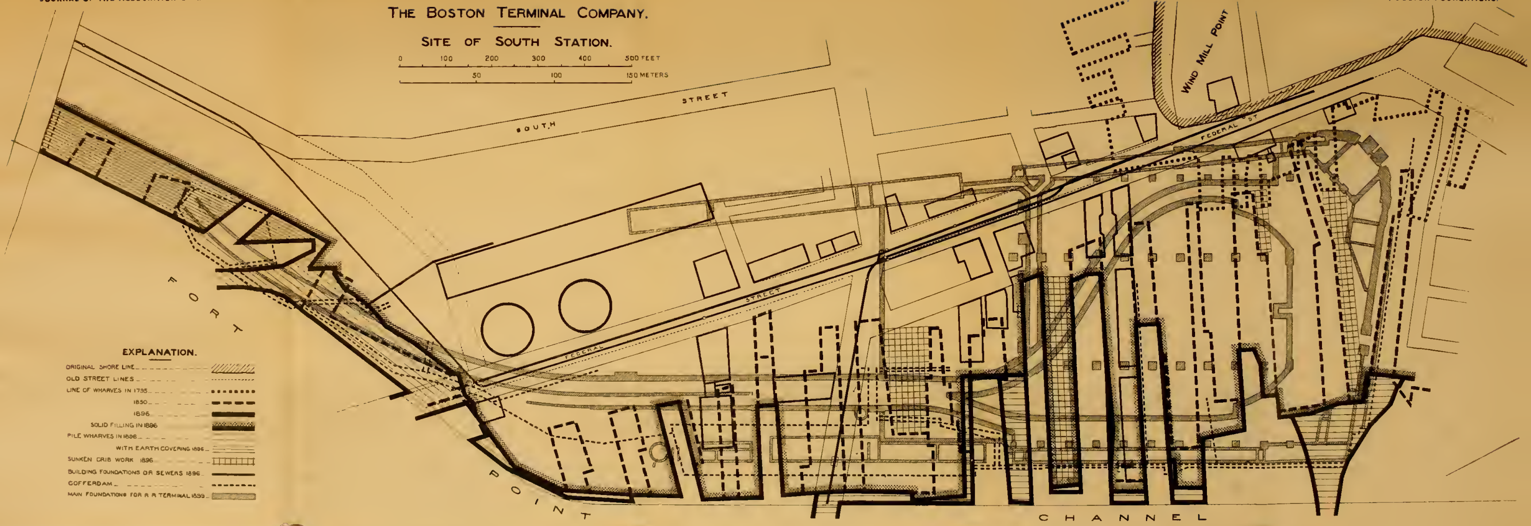
In considering the loads we have to carry, there is no provision in the Boston building law, such as is often found in modern build-

*Manuscript received May 11, 1903.—Secretary, Ass'n of Eng. Socs.

ing laws, by which less than the full live load can be assumed to reach the bottom of the columns. According to the ruling of our Board of Appeal, it is not legal to calculate on less than the full specified live load on each floor in designing any part of the structure. In the columns, where definite strains per square inch are allowed by the law, we are allowed no discrimination, but in the case of foundations the law does not specify the allowable load per pile or per square foot, and we can, if we desire, increase the unit under the full load in inverse ratio to a rational change in the total load.

It may at first sight seem unsafe to take advantage of this; but, if we look at it in another way, it appears more plausible. Suppose the law said that the columns of a certain building were to be designed to carry a live load of 100 pounds per square foot on all the area of all the floors of a building, and we were allowed to use our judgment in designing the floor beams, what loads would we want to figure these beams for to make sure that the building was harmoniously designed and that the beams were proportionately as strong as the columns? If we consider the possibility of local concentrations in any form of loading, we should probably not feel safe in taking for the maximum local load less than the equivalent of 200 pounds per square foot distributed. That being the case, and bearing in mind the fact that it is scarcely possible to get a load over every square foot of floor space without leaving aisles through which the load may be reached, it seems as if we would be amply justified in assuming that not over 50 per cent. of the total live load on all floors reaches the foundations. In certain classes of buildings it may be even allowable to consider less than this proportion. For instance, in office buildings the law requires us to figure for 100 pounds per square foot, and, considering the heavy loads often applied to single beams through safes, bookcases and piles of papers, this is not an unreasonable allowance. But by the time we reach the foundations our total load is made up of the accumulation of so many square feet that, in the writer's opinion, it would be abundantly safe to reduce this live load to 25 pounds per square foot.

In fact, in order to proportion the foundations properly, it is necessary to make some such reductions in the live load; for it would be unwise, and might make trouble, to have the different foundations in the same building loaded very unequally. If any settlement occurs, it makes all the difference in the world whether the whole building goes down equally or whether one foundation goes down and the next does not. Now, it is almost always the


THE BOSTON TERMINAL COMPANY.
SITE OF SOUTH STATION.
0 100 200 300 400 500 FEET
50 100 150 METERS
SOUTH STREET
FEDERAL STREET
FEDERAL ST
WIND MILL POINT
FORT POINT
CHANNEL
EXPLANATION.
ORIGINAL SHORE LINE
OLD STREET LINES
LINE OF WHARVES IN 1795
1850
1896
SOLID FILLING IN 1896
PILE WHARVES IN 1896
WITH EARTH COVERING 1896
SUNKEN CRIB WORK 1896
BUILDING FOUNDATIONS OR SEWERS 1896
COFFERDAM
MAIN FOUNDATIONS FOR R R TERMINAL 1899

case that some of the foundations, such as those of interior columns, carry nothing but floor loads, while those under walls often have no live load at all. Consequently, if we figure in literal accordance with the law, we shall be allowing for the actual constant load under the wall, while the foundation under the interior column will be figured for a load which may easily be double what will usually come on it, and perhaps 60 per cent. more than the maximum it will ever get.

In what follows it will be assumed that a fair allowance is made for a reduced live load and that the load we provide for is not the extreme one required by law.

The geologic formation of the "Boston Basin," so called, is very fully explained in a report by Prof. W. O. Crosby, published as an appendix to the fifth annual report of the Boston Transit Commission, August 15, 1899. In substance this report explains that the underlying rock, a slate formation, is at a depth of from 50 to 170 feet below low water. This is overlaid with a boulder clay in the form of smoothly rounded hills or drumlins, the thickness of which is from 15 to 90 feet. Above the boulder clay is found a layer of blue clay, a true glacial deposit, generally a very tough, plastic clay, free from grit, but containing a large proportion of quartz flour with occasional thin layers and streaks of very fine sand with occasional angular fragments of rock. This clay reaches an extreme elevation of about 5 feet above high tide and was deposited in even, horizontal layers. At its higher levels and everywhere above low tide this clay has been oxidized to a buff or yellow color, but this, as well as the blue clay, is of a very stiff, tough and impervious character. Where the clay has been eroded we often find silt or a fine muddy sand, and this often covered with peat.

The profiles exhibited herewith show clearly this general formation, or, at least, the upper portion of it, in the northern and eastern portion of the peninsula; and the appended tables of borings, for which we are chiefly indebted to Mr. William Jackson, city engineer of Boston, to Mr. H. A. Carson, chief engineer of the Boston Transit Commission, and to Mr. George A. Kimball, chief engineer elevated lines, Boston Elevated Railway, give further evidence of the same general condition of the soil. Along the shore line and between the present shore line and the original line we encounter all sorts of conditions. A great deal of wood is found, generally in sound condition, and numerous old sea walls are encountered, sometimes causing a good deal of trouble. The accompanying plan of the property of the Boston Terminal Company, kindly furnished by Mr. George B. Francis, shows about as great a variety of conditions as could well be obtained in the same space.

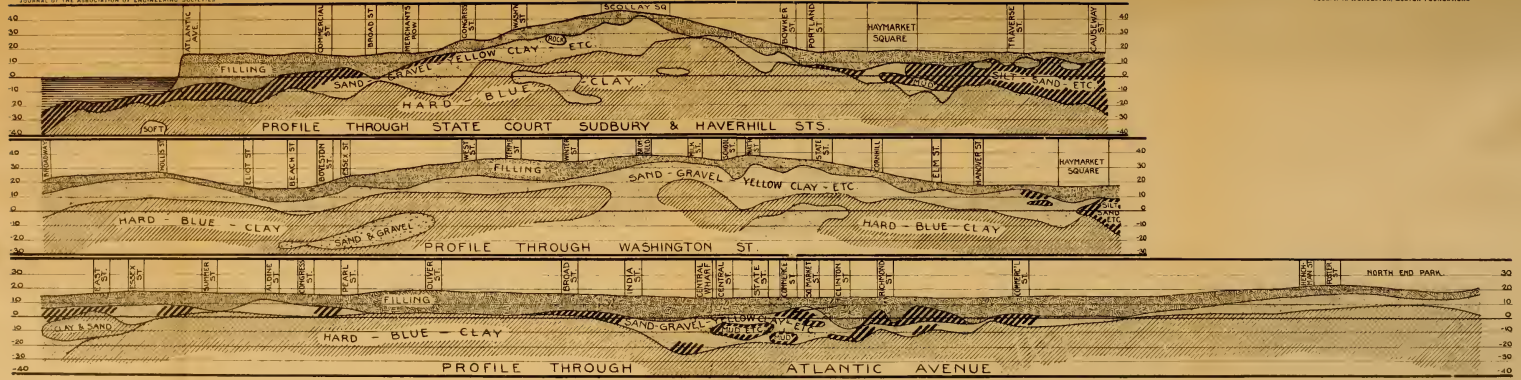
The result of this formation is that solid rock is so far below the surface that we do not encounter it, either as an aid or as a hindrance, in our Boston work.

In a general way we have two distinct classes of foundations, and only two. We either support our structures upon piles or directly upon the soil, which is sometimes pure clay, either blue or yellow, sometimes fine sand, almost clean, sometimes gravel, consisting of stones running from coarse sand up to small boulders, and sometimes any possible combination of these substances.

The line of demarkation between the two classes of foundations is not very definitely located on the map of the city. In general, it may be said to follow the original shore line of the peninsula, more or less closely. This line is shown on the map by the heavy dotted line. But there are a number of places where the hard foundation has been found near enough the surface to make it possible to dispense with piles even outside of the present shore line, as, for instance, in the Charlestown Bridge, where the Charlestown abutment and piers Nos. 1 and 2, counting from Charlestown abutment, have no piles. Other instances of the omission of piles can be found in the buildings located in the cove making up across State Street to Post Office Square. The Delta Building, the Fiske Building and many others, down as far as the Board of Trade Building, have no piles under them. On the line of the Atlantic Avenue division of the Boston Elevated Railway, on the other hand, the portion between Summer Street and Broad Street, and from the corner of Commercial Street and Atlantic Avenue to Charter Street, skirted the original shore line, the remainder being outside the old line. On this line piles were used only in Beach Street and up to Summer Street, and again in the space between Broad and Commercial Streets, which parts were outside the original line, thus following the general rule closely.

Pile foundations may be divided into two distinct classes: First, those where the piles pass through the filled material and often layers of peat, silt, beach sand and mud to a hard underlying stratum of clay or clay mixed with more or less sand and gravel. Second, those where the piles hold by friction only and, no matter how far they are driven, do not reach a point where the penetration is suddenly arrested.

Both of these classes of pile foundations were discussed in the paper by Mr. H. J. Howe, presented to the Society March 30, 1898, and in the full discussion which followed; but in that discussion attention was chiefly directed to unusual cases, while it is the


SCOLLAY SQ
ATLANTIC AVE.
COMMERCIAL ST
BROAD ST
MERCHANTS ROW
CONGRESS ST.
WASH'N ST
BOWKER ST.
PORTLAND ST
HAYMARKET SQUARE
TRAVERSE ST.
CAUSEWAY ST.
FILLING
ROCK
YELLOW CLAY - ETC.
SAND - GRAVEL
HARD - BLUE - CLAY
MUD
SILT
SAND - ETC.
SOFT
PROFILE THROUGH STATE COURT SUDBURY & HAVERHILL STS.
BROADWAY
HOLLIS ST
ELIOT ST
BEACH ST
BOYLSTON ST.
ESSEX ST
WEST ST.
TEMPLE PL
WINTER ST
BROMFIELD
MILK ST.
SCHOOL ST
WATER ST
STATE ST.
CORNHILL
ELM ST.
HANOVER ST
HAYMARKET SQUARE
FILLING
SAND - GRAVEL - YELLOW CLAY - ETC.
HARD - BLUE - CLAY
SAND & GRAVEL
SILT SAND ETC
PROFILE THROUGH WASHINGTON ST.
EAST ST.
ESSEX ST
SUMMER ST
ALDINE ST
CONGRESS ST
PEARL ST.
OLIVER ST.
BROAD ST.
INDIA ST.
CENTRAL WHARF
CENTRAL ST.
STATE ST.
COMMERCE ST
SO MARKET ST.
CLINTON ST
RICHMOND ST
COMMERC'L ST.
HENCHMAN ST
FOSTER ST
NORTH END PARK.
FILLING
CLAY & SAND
HARD - BLUE - CLAY
SAND-GRAVEL-YELLOW CLAY ETC
MUD ETC
MUD
PROFILE THROUGH ATLANTIC AVENUE
40
30
20
10
0
-10
-20
-30
-40

purpose of this paper to touch more particularly upon the ordinary, every-day foundations commonly encountered.

The questions with which we are generally concerned are:

First. What is the best and most economical way to pile for a foundation?

Second. What loads is it safe to place on piles?

Third. At what grade should piles be cut?

Fourth. How should foundation piles be capped?

Under the first head we may consider what kind of piles to use, what size, how close they can be driven to advantage, and what should be specified as to weight and fall of hammer and what penetration can be allowed?

The cheapest piles in the Boston market are spruce. They come here in lengths from 20 to 50 feet, with diameters running from 4 to 6 inches at the tip and from 10 to 12 inches at the head. Of course, the length, in case they are driven into a resisting stratum, is determined by local conditions, but the size is a matter for the engineer to determine. The city of Boston specifications for bridge piers and abutments require piles 6 inches in diameter at the point. The Boston Transit Commission specifications for the subway required the same size. The Boston and Maine Railroad specifies 7 inches at the tip and 11 inches where cut off for the masonry. Architectural specifications vary very considerably and often omit the size altogether, allowing that a pile is a pile, no matter what size. The present writer's judgment is that it is unnecessary to specify the size at the butt, and that a spruce pile 6 inches in diameter at the tip is sufficient for all ordinary cases of foundations. All measurements should be under the bark.

In cases where the piles hold by friction only it sometimes occurs that a greater length of pile is desirable than can be obtained in spruce. If so, there are two species sometimes used, hard pine and Norway pine. Hard pine piles can be obtained up to 80 feet in length, in which case the diameter at the butt will be about 16 inches. Norway pine can be obtained up to about 75 feet in length, with a butt diameter of about 16 inches. The Norway pine piles are generally a little cheaper and practically as good.

The minimum distance between centers of piles depends upon two factors: the hardness of the soil and the size of the butts. Ordinary spruce piles may be well driven 24 inches on centers, while large and long piles cannot be driven to advantage closer than 30 inches. Another governing condition must be taken into account, however, and that is the supporting power of the soil as a whole. Where the piles reach a real hard pan, the soil will

generally resist all the pressure that the piles can bring on it, unless it consists of a thin crust overlying a soft material; but when the soil is so soft that the piles hold by friction only, and there is enough friction to carry all the soil between the piles down with them, in case they go together, the spacing becomes a question of how much the underlying soil will support per square foot. For example, if the soil can only support 2 tons per square foot, and the piles could each carry 18 tons, it is useless to place them closer than 3 feet on centers.

Perhaps there is no point on which we find greater variation in specifications than in the requirements as to weight of hammer, height of fall and penetration. The writer has seen a foundation where the architect specified a 2500-pound hammer, falling 20 feet, with a penetration of ½ inch, where some of the piles actually had a penetration of 9 inches with 1800-pound hammer falling 10 feet. And yet the architect was obliged to accept them, as he could do no better.

In the case of the piles being driven into hard stratum there is danger of too hard driving crushing or crippling the pile, and it is much better not to punish such piles too severely. As to the weight of the hammer, it is always better to have a heavy weight falling a short distance than a light hammer falling a long distance. The Boston and Maine Railroad specifies a 2600-pound hammer falling 15 feet, with a penetration not exceeding 16 inches in the last ten blows. The city of Boston, the Transit Commission and some architects do not specify either the weight of the hammer, the fall or the penetration, but simply that the piles shall be driven to a firm bearing to the satisfaction of the engineer. With competent expert services, this is perhaps the best method of specifying, but, to enable the contractors to estimate closely, and where the supervisor is not an experienced engineer, it is well to have some definite figures stated. Before making a specification it would be wiser to determine, by borings, what the nature of the soil is likely to be, whether the piles are to meet a hard resistance or must hold by friction, and in the former case the writer would advise specifying a penetration of 1 inch under a 2000-pound hammer falling 10 feet, and in the latter a penetration of 3 inches under a 2000-pound hammer falling 15 feet. It would, perhaps, be better to require heavier hammers, but for building work it is not easy to get them.

As was clearly pointed out in the discussion of Mr. Howe's paper, and as we all know from experience, friction piles in our soils derive a great increase in resisting power by a few hours' rest after driving, and, so far as the writer's knowledge goes, it is en-

tirely safe to rely upon this increase in resistance, for time does not decrease it again, even though the load may be subject to considerable vibration. In some kinds of sand this may not be the case, but with clay it seems to hold.

Coming now to the second inquiry, as to the safe loads for ordinary piles, we reach a subject upon which a great deal has been written. Much valuable matter was collated on this subject by Mr. Howe in the paper above referred to, and more recently a very interesting graphical table has been presented to the American Society of Civil Engineers by Mr. Ernest P. Goodrich (Trans. American Society Civil Engineers, Vol. XLVIII, p. 211), which gives the ultimate load allowed by seven different formulæ for certain penetrations under hammers weighing 3000 pounds, 2000 pounds and 1000 pounds, falling 15 feet. As we understand it, Trautwine's formula is here incorrectly stated and plotted, as the curve should come about 4.5 times higher. If we place Trautwine's curve where it should be, and neglect Weisbach's short formula, which gives very high results, we find, in the diagram for a 2000-pound hammer with a penetration of 1 inch, loads from 40 to 85 tons, and, for a penetration of 3 inches, loads from 13 to 40 tons, showing that there is a good deal of variety of opinion as to the actual capacity of piles.

An old rule, quite generally followed by Boston architects, is to call 10 tons the safe load for a pile, though many follow the *Engineering News'* formula in figuring their foundations, and then take their chances as to whether the conditions of penetration, weight and fall of hammer, upon which they base their calculations, are obtained in construction, seldom revising their design in case the results vary widely from the assumptions.

If we take the specifications for driving recommended previously, viz, for piles to be driven into a hard pan a 2000-pound hammer falling 10 feet with a penetration of 1 inch, and for friction piles the same hammer and a fall of 15 feet with a penetration of 3 inches, and apply in the formulæ given by Mr. Goodrich, we get for the first class of piles ultimate loads varying from 32½ tons to 65 tons, and for the second class loads varying from 13 tons to 40 tons, or, averaging between the extremes, ultimate loads for the first class of 48¾ tons and for the second of 26½ tons. With a factor of safety of 3, this would give safe loads on the first class of 16 tons and on the second class of 9 tons, and these results seem to be perfectly safe in view of all the tests with which the writer is acquainted.

We come now to the third inquiry propounded with regard to

pile foundations, viz, What is the proper grade at which piles should be cut?

It has generally been assumed by engineers that the only point necessary to consider with regard to the grade at which piles should be cut is how high we can be sure that they will always be wet, and there is an unwritten law in this vicinity that 5 feet above city base, or about half tide, is a safe level to accomplish this result. Some engineers have even held that at a point higher than this the piles would never dry sufficiently to allow rotting to take place.

There is, however, another possibility which should be borne in mind.

When the old building of the Boston Electric Light Company, on Summer Street, was removed in the fall of 1901, it was found that the tops of many of the piles were badly wasted. These piles were cut at about grade 7 feet 6 inches, and on the tops of them rested granite levelers. The appearance of the piles from a little distance led many to suppose that the tops were rotted. One of our members, Mr. H. K. Higgins, wrote for *Engineering News* an article on the subject, which was illustrated with a photograph showing many of the piles as seen from the street.* This article called forth a comment from the esteemed editor, severely censuring the people responsible for such construction, and the information thus widely circulated has been noted by many engineers, not only in this vicinity, but all over the country. It is unfortunate that the story was not wholly correct, though perhaps the effect of the publication has been none the less wholesome on account of the error as to details. The cause of the trouble in this case was not rot, as stated, but worms. This was clearly seen by a close examination of the piles. Mr. E. L. Rawson, the architectural superintendent, is our authority for the foregoing figures and can bear testimony as to the cause of the trouble.

It seems that, in this locality, at the time the building was constructed, tide water had free access to the foundations at each tide, and that, undoubtedly, if the soil ever was even with the tops of the piles, it washed out or subsided enough to leave a few inches of each pile unprotected by earth and gave the worms a chance to get in their work in this space.

Whether the concrete floor above the foundations retained enough air when the tide rose to keep the piles on the border line of air and water is not certain, and whether the worms could have worked if they had been flooded at each tide the present writer is unable to say; but there is no doubt that, under similar conditions, it is extremely important that their chance for operations should be

*See page 314.

prevented. After a building is constructed, it is very rarely that we have the opportunity to make an examination of the piles, and it is not a pleasant thought for the owner of the property to have in his mind that worms may be gnawing away at the vitals of his property and that some day it may suddenly slump. As a suggestion which it is hoped other members may freely criticise, the writer would advise that, where tide water has access to the piling, the masonry shall be started not higher than grade 4, but, where fully surrounded with fill, the masonry may start at 5.

This consideration leads naturally to the last question offered on the subject of pile foundations, that is, What is the best method of capping?

To refer again to the Boston building law, we find it here required that "all piles shall be capped with block granite levelers." This would seem to exclude the possibility of capping with concrete, but in a number of recent buildings the architect has shown concrete laid directly upon the piles. In carrying out the provisions of the law the building commissioner rules against these plans and the architect has to go to the Board of Appeal, and this body allows the technical infraction of the law. This, in the writer's opinion, is clearly the proper action. The reason that the law is so prejudiced against the use of concrete, as it is understood, is that if concrete were allowed it would be difficult to prevent unscrupulous contractors from using such poor material that it could not resist the pressure brought by the pile head, that is, perhaps, 16 tons on, say, 70 square inches, or 460 pounds per square inch. This may be rather a high pressure, but it would seem as if the law might cover the specification for concrete in sufficient detail to make it safe. The best possible method of capping is to cut the pile as level as possible, to clean out all dirt and loose material between and around the piles and to start concrete on the remaining soil.

Foundations not requiring piles are usually of simple character and do not require any great amount of engineering. In the higher parts of the city, where the soil consists either of sand or of sand and gravel mixed, the foundations are about as satisfactory and easy to deal with as if they rested upon solid ledge.

The soil in these parts of the city would probably carry upward of 10 tons per square foot without appreciable settlement, though the writer is not acquainted with any tests definitely proving the capacity. Architects very frequently assume 5 tons per square foot as a safe load, and this appears to be a conservative figure.

The Boston building law allows the use of concrete for "foot-

ings," but not for "foundations," and an interesting question is opened as to where the footings stop and the foundations begin. There is not a very great difference between the cost of concrete and of block granite foundations, and it is most common to use granite for the entire foundation in hard ground, or for all except a footing course of about 2 feet thickness; but there is no doubt that with good concrete results could be secured as satisfactory in every way by carrying the concrete up to near the surface grade, and in some cases where this has been done the Building Department has not interfered.

In the lower section of the city, where the foundations go down into the clay, we often encounter material which is quite wet and not very hard. When these foundations have to be carried down to considerable depths to provide for sub-basements it is always necessary to do more or less pumping. While the clay itself is quite impervious, there are almost always streaks of sand or gravel, as noted in Professor Crosby's report, which carry some water, and to get rid of this it is necessary to pump, though, as far as the writer's observation has gone, the pumping has not been excessive. The only trouble from it is that long-continued pumping from a deep excavation lowers the level of the ground water under surrounding buildings, and sometimes this produces settlements. It is, therefore, advisable to shorten the time of pumping as much as possible.

The sand, where it occurs, is frequently extremely fine, and it is carried to some extent by the water, though sometimes it is so compacted that quite a stream of water will flow through it without breaking it down. In many places in the city it has been called "quicksand," but, probably, this term is not properly applied to anything encountered in this soil. We have heard rumors of "quicksand" under the Exchange Building, the Hospital Life Building, the Worthington Building, the Suffolk Trust Building, the Globe Building, the Winthrop Building, the Jewelers' Building, and in other places, but, with the possible exception of the last, the people most interested have, when questioned, stated that the troublesome material was a "running" sand and, though similar, probably not real quicksand. Where these streaks are encountered in the sides of an excavation they can generally be controlled by close sheeting, and where they are at the bottom of an excavation that is as deep as required for other reasons it is possible to fill in on top of them with gravel or crushed stone, upon which concrete can well be laid.

In low cellars, below grade 8 or 10, it is generally necessary

to make a close bottom and wall and to waterproof throughout. Waterproofing can be best inserted between two thicknesses of masonry. On the bottom of the excavation one of the best methods of applying is to lay sub-drains over the soil bedded in a layer of gravel and over this about 6 inches of concrete, the drains running to a sump which can be pumped. The waterproofing can then be laid over the concrete, and enough concrete over the whole to hold the waterproofing down. On the sides a thin wall of brick or concrete can be built against the sheeting and the waterproofing applied to this, and afterward the main wall built inside of the waterproofing. It will often save annoying leaks if the bottom sheet can be made in one unbroken layer, though it is generally necessary to carry foundations for interior columns down to a lower grade than the regular bottom level. In such cases it is better to run the waterproofing through the column foundations than to try to drop down under them. Sometimes it becomes necessary to waterproof the side walls inside of the main wall, and it is then an interesting question how thick the lining must be to resist the water pressure. It is certain that it is not necessary to calculate a full hydrostatic pressure, for the reason that the whole of the back of the waterproofing is not exposed to the water. Very often 4-inch or 8-inch brick linings are used where at considerable depths below water level, but just what is a safe proportion of the hydrostatic pressure to allow is a matter upon which the writer would like to be informed.

Another engineering question, of interest with regard to deep foundations, is whether retaining walls should always be calculated to have stability enough from vertical load alone, or whether it is safe to count on their being braced horizontally by an interior steel framing, assuming the latter to be properly designed to take and resist the pressure. In the subway it was assumed that the roof furnished a horizontal support for the side walls, which were figured as beams, and, indeed, mostly constructed with steel beams. This appears to be equally justifiable in the case of steel skeleton buildings, and it results in considerable economy.

As to what load may safely be allowed upon foundations in the lower parts of the city, a great deal depends upon the wetness of the soil. The softest clay which has come under the writer's notice hereabouts can probably carry with perfect safety 2½ tons per square foot, and from this the capacity runs up to as much as 4 tons. It is somewhat difficult to predict from borings the relative hardness, and it is often found necessary to increase the size of foundations after excavating. The most economical way of arranging for

this, but one seldom adopted in building construction, is to design the foundations for a pressure which seems probably safe, but not extravagantly so, and have a unit price agreed upon with the contractor to cover additions should they be found necessary.

There is one point of which we must take account, but which is quite frequently overlooked, and that is the unequal distribution of the load over the bottom of the foundation on account of its being eccentrically placed. This system applies to all cases of foundations and is, no doubt, of less consequence in hard ground than in soft, but is always of more or less importance. In very many cases buildings have to be constructed against lot lines and the foundations entirely confined to one side of the line, and where not only the walls, but often heavy columns, are placed as near the line as possible, it becomes a matter of some difficulty to get a concentric bearing on the soil. Ten or fifteen years ago it was the common practice of architects to extend such foundations inward, leaving the outer face vertical against the lot line. In some cases they were extremely particular to limit the pressure on the soil to a certain figure without regard to whether the bearing was eccentric or concentric, while, if proper allowance is made for eccentricity, it will be found that the pressure on the loaded side is sometimes extremely high, though it has seldom led to trouble where the soil is hard. One of these cases which has come under the notice of the writer was where extremely heavy loads were carried upon friction piles. The architect calculated that the piles were not loaded over 11 tons per pile, while, if proper account was taken of the eccentricity, those next the property line are found to have carried over 31 tons per pile, and it is not surprising that slight settlement and cracks occurred.

About ten or fifteen years ago the system of supporting such loads next to property lines upon cantilever girders came into use, and since that time Boston architects have very largely employed this system where they realized the necessity. In the case of cantilever girder construction it is of great importance to know the safe resisting power of the soil, for a difference of assumption of 1 ton per square foot means a very great difference in the cost of the cantilevers. It is hoped that those who have definite information upon this subject will make it known in the interest of general economy of construction.

In some of the narrow buildings recently built foundation girders have been used running the entire width of the building and supporting a column at each end. In one case, that of the extension to the Boston Athletic Association Building, now being constructed,

such foundation girders are being used, which are concrete-steel construction, the steel being in the shape of Ransome system twisted rods.

An instance of the effect of eccentricity of loading on piles, and also of the use of cantilevers in foundations, was found in the supports of a 200-foot chimney built in the Atlantic Avenue district about a dozen years ago. This stack was placed not far from what was then the boundary line of the owner's property, and it so happened that an old sea wall ran along about under the party line. The location was so near tide water at the time that to remove the wall would have required divers, and it would also have involved more or less trespass upon the neighbor's property, which it was very important to avoid. Under the foundations there is about 90 feet of clay, which is uniformly plastic, neither very hard nor very soft, but making it necessary to rely upon friction piles. These were driven about 2 feet on centers close up to the sea wall and extending back so as to make a base about 26 feet square, but with its center about 3 feet from the center of the stack. The weight of the stack and masonry foundation was about 2875 tons, which produced an average pressure of about 11.8 tons per pile, but an actual pressure, allowing for eccentricity, upon those most highly loaded of 29 tons per pile.

Soon after the stack was completed it was found that the top was gradually moving toward the weak side, and it became necessary, to prevent more serious trouble, to go across the lot line. Under the direction of the late Horace W. Ball, C.E., a strip of the abutter's property was taken, at right angles to the lot line opposite the center of the stack and running some 30 feet from the stack, and this strip was driven full of piles. Over these were laid 15-inch I-beams, the heaviest obtainable at the time, extending to the stack and getting a bearing under the weak side of it, and upon these beams was built a triangular piece of brick wall the full length of the beams at the bottom and extending upward to a point about 40 feet up on the stack, into which it was bonded, the outer end of the wall being on a slope. This formed, in effect, a sort of buttress, the pressure of which furnished the anchorage for the cantilever beams. The result was all that could be desired, the motion ceasing from that time. About three years ago—that is, about nine years after the stack was built—the owners secured the adjacent property and extended their building, and in the process of remodeling it became necessary to remove this buttress, though the old beams were left in. Soon after this was done, however, a crack appeared on the opposite side of the stack between it and

the wall which adjoined it there and which was some 80 feet high. Careful observations of the stack were made, and it was reported by the surveyors that the top was moving, though the motion must have been very slight, if it really took place at all. Around the base of the stack there were also some small cracks discovered that had not been noticed before, which seemed to indicate that the foundations were not stable. It was, therefore, decided to provide more support in some way. An excavation was made on one side of the original buttress up to the old sea wall and as much of this was removed as was possible without disturbing the masonry under the stack, which, by the way, had been carried out on to the sea wall. It was found possible to get in a group of twenty 50-foot piles, the center of which was about 20 feet from the stack, and they were so driven and capped with concrete up to a grade about 4 feet below the floor line of the building. Over this concrete as a fulcrum were placed eight beams 24 inches by 80 pounds by 60 feet, one end of which was inserted under the stack. Under the tail of the cantilever thus formed was placed a block of concrete weighing about 180 tons and supported upon piles. In this concrete were imbedded anchors provided with rods extending up to the top of the beams and furnished with nuts working on long threads. By means of these adjustable anchor rods the tail of the cantilever was then drawn down until each beam had an upward deflection amounting to about 3½ inches, which would indicate a fiber strain in each approaching the elastic limit of the steel. The beams were then filled in with concrete over their whole length and the concrete was carried up to grade. The effect of this arrangement was to give an additional support on this side of the stack of about 90 tons, and, assuming that the surrounding concrete increased the strength of the beams, this assistance may be considerably greater. While this is not enough to fully equalize the load on the piles under the stack, it has served its purpose, as no further motion has taken place.

The map of the city exhibited herewith has been prepared by Mr. E. E. Pettee, member of the Boston Society of Civil Engineers. In addition to the original shore line and present extent of the city, it shows the location of the borings shown in the accompanying diagrams. It is hoped that, as time goes on, it will be possible to add additional borings on this same map, making it a partial record of what has been definitely determined with regard to the soil, and members of the Society are invited to supply such records as they have in their possession for this purpose.

The diagrams of borings indicate, by scale, the depths of the different strata of soil and, by numbers, the material found in each.

The explanation of the numbers is in the following table, where the different kinds of material are described.

CLAY OR BLUE CLAY COMBINATIONS.

100. Soft blue clay.
101. Soft wet blue clay.
102. Hard blue clay.
103. Hard wet blue clay.
104. Blue clay, yellow clay, sand, hard.
105. Fine clay, sand.
106. Clay, fine sand, wet.
107. Clay, fine blue sand, wet.
108. Clay, fine yellow sand.
109. Clay, sand.
110. Clay, fine sand.
111. Hard blue clay, little sand.
112. Hard blue clay, fine sand.
113. Hard blue clay, little fine sand.
114. Hard clay, gravel.
115. Hard blue clay, fine gravel.
116. Blue clay, fine sand, gravel.
117. Hard blue clay, sand, gravel.
118. Clay, sand, coarse gravel.
119. Clay, sand, gravel, hard.
120. Clay, coarse sand, gravel, hard.
121. Little clay, sand, coarse gravel.
122. Hard, blue clay, sand, fine gravel.
123. Clay, sand, gravel, mud.
124. Clay, sand, gravel, stones, hard.
125. Clay, sand, stones.
126. Clay, sand, stones, hard.
127. Clay, sand, little stones.
128. Clay, little sand, stones.
129. Clay, sand, shells.
130. Clay, gravel, stones, hard.
131. Clay, mud, stones, hard.
132. Hard clay, stones.
133. Clay, gravel.
134. Blue clay, stones.
135. Hard blue clay, sand.
136. Hard clay, little sand, stones.
137. Hard clay, fine stones.
138. Clay, silty sand, gravel.
139. Clay, sandy gravel.
140. Blue clay or clay.
141. Clay, mud, stones.
142. Fine clay, mud, stones, hard.
143. Hard blue clay, little gravel.
144. Little clay, sand, gravel, soft.
145. Blue clay, fine sand.
146. Clay, fine sand, fine gravel.
147. Blue clay, sand, gravel, stone.
148. Soft blue clay, sand.
149. Soft blue clay, little sand.
150. Hard fine blue clay.
151. Little clay, fine blue sand.
152. Little coarse, hard fine sand, gravel.
153. Hard blue clay, sand, little gravel.
154. Clay, coarse sand, gravel.
155. Clay, mud.
156. Clay, gravel, mud.
157. Little clay, silt.
158. Hard blue clay, little sand, gravel.
159. Soft clay, mud.
160. Soft clay, gravel.
161. Clay, fine brown sand.
162. Clay, black mud.
163. Clay, hard gravel.
164. Clay, yellow sand, stones.
165. Clay, yellow gravel.
166. Clay, sand, coarse gravel, hard.
167. Hard clay, coarse sand.
168. Little clay, sand.
169. Clay, little sand.
170. Silty clay, sand, shells.
171. Blue clay, little fine sand.
172. Hard blue clay, little sand, little gravel.
173. Little clay, sand, silt.
174. Little clay, sand, gravel.
175. Little clay, sand, little gravel.
176. Little clay, blue sand.
177. Clay, blue sand.
178. Little clay, fine sand.
179. Clay, fine blue sand.
180. Hard clay, little sand, little gravel.
181. Clay, coarse sand.
182. Clay, sand, gravel, shells.
183. Blue clay, coarse gravel.
184. Clay, hard blue sand, gravel.
185. Little clay, sand, gravel, hard.
186. Clay, gravel, stones.
187. Clay, little gravel.
188. Little clay, gravel.
189. Clay, brown sand.
190. Little clay, blue sand, gravel.
191. Hard blue clay, coarse gravel.

192. Clay, yellow sand.
193. Fine blue clay, sand.
194. Clay, brown sand, gravel, hard.
195. Coarse brown clay, sand, gravel, hard.
196. Blue clay, sand, coarse gravel, hard.
197. Clay, sand, fine gravel.
198. Clay, sand, gravel, wet.
199. Little clay, fine yellow sand, silt.

YELLOW CLAY COMBINATIONS.

200. Soft yellow clay.
201. Hard yellow clay.
202. Hard yellow clay, wet.
203. Hard yellow clay, sand.
204. Hard yellow clay, fine sand.
205. Hard yellow clay, little fine sand.
206. Hard yellow clay, sand, gravel.
207. Hard yellow clay, sand, blue gravel.
208. Hard yellow clay, fine sand, gravel.
209. Yellow clay, sand, gravel.
210. Hard yellow clay, sand, gravel, stones.
211. Hard yellow clay, sand, gravel, shells.
212. Yellow clay, sand, gravel, hard.
213. Yellow clay, gravel, hard.
214. Yellow clay, gravel.
215. Yellow clay, sand.
216. Yellow clay, fine sand.
217. Hard yellow clay, fine sand.
218. Yellow clay, sand, coarse gravel.
219. Hard yellow clay, little sand.
220. Soft yellow clay, sand.
221. Soft yellow clay, sand, gravel.
222. Yellow clay, stones.
223. Yellow clay, gravel, stones.
224. Yellow clay, little sand, stones.
225. Coarse yellow clay, hard.
226. Hard yellow clay, sand, coarse gravel.
227. Yellow clay, sand, stones.
228. Yellow clay, sand, little gravel.
229. Hard yellow clay, little gravel.
230. Yellow clay.
231. Yellow clay, little sand.

SAND COMBINATIONS.

300. Sand.
301. Brown sand.
302. Coarse sand.
303. Coarse wet sand.
304. Wet sand.
305. Fine sand.
306. Fine wet sand.
307. Fine yellow sand.
308. Fine blue sand.
309. Fine wet blue sand.
310. Fine sharp sand.
311. Fine sharp wet sand.
312. Sharp yellow sand.
313. Sand, gravel.
314. Sand, gravel, wet.
315. Fine sand, gravel.
316. Fine sand, gravel, wet.
317. Coarse sand, gravel.
318. Coarse sand, gravel, wet.
319. Sand, gravel, hard.
320. Sand, gravel, coarse, hard.
321. Coarse sand, fine gravel.
322. Fine sand, fine gravel.
323. Fine yellow sand, fine gravel.
324. Coarse sand, fine gravel, black silt.
325. Silty sand, gravel.
326. Fine silty sand, fine gravel.
327. Sand, gravel, silt.
328. Sand, gravel, silt, mud.
329. Sand, gravel, silt, mud, shells.
330. Sand, fine gravel. silt, shells.
331. Sand, gravel, mud.
332. Sand, gravel, black mud.
333. Sand, gravel, stones.
334. Sand, gravel, stones, hard.
335. Coarse sand, fine gravel, shells.
336. Fine sand, silt.
337. Fine yellow sand, silt.
338. Black sand, silt.
339. Fine silty sand.
340. Soft fine silty sand.
341. Fine silty sand, mud.
342. Sand, silt, mud.
343. Sand, silt, blue mud.
344. Fine sand, silt, mud, shells.
345. Black sand, silt, mud, shells.
346. Silty sand, shells.

347. Fine silty sand, shells.
348. Soft fine silty sand, shells.
349. Fine sand, silt, shells.
350. Fine sand, blue silt, shells.
351. Fine muddy sand.
352. Sand, mud.
353. Yellow sand, mud.
354. Brown sand, mud.
355. Coarse sand, mud.
356. Sand, mud, shells.
357. Fine sand, shells.
358. Soft wet sand, shells.
359. Yellow sand, stone, wet.
360. Yellow sand, fine stones.
361. Silty sand.
362. Yellow sand.
363. Coarse sand, gravel, hard.
364. Fine sand, hard.
365. Fine sand, gravel, hard.
366. Blue sand, gravel.
367. Hard silty sand.
368. Soft silty sand.
369. Hard blue sand, gravel.
370. Little sand, silt.
371. Fine sand, mud.
372. Little sand, hard silt.
373. Silty sand, mud, shells.
374. Silty sand, little mud, shells.
375. Sand, mud, stones.
376. Sharp wet sand, shells.
377. Sand, coarse gravel.
378. Silty sand, gravel, hard.
379. Sharp yellow sand, little gravel.
380. Yellow sand, little gravel.
381. Coarse sand, little gravel.
382. Coarse sand, gravel, shells.
383. Sand, gravel, timber.
384. Fine sand, silt, shells, piles.
385. Sand, fine silt, shells.
386. Sand, gravel, shells.
387. Coarse blue sand.
388. Coarse brown sand.
389. Blue sand.
390. Sand, stones.
391. Sand, little stones.
392. Yellow sand, gravel.
393. Yellow sand, stones.
394. Sand, coarse yellow gravel.
395. Sand, stones.
396. Coarse yellow sand.
397. Fine hard yellow sand.
398. Fine brown and blue sand.
399. Hard fine blue sand.

GRAVEL COMBINATIONS.

400. Gravel.
401. Soft gravel.
402. Fine gravel.
403. Hard gravel.
404. Fine blue gravel.
405. Fine wet gravel.
406. Coarse gravel.
407. Black gravel, mud.
408. Black gravel.
409. Gravel, mud.
410. Gravel, shells.
411. Gravel, shells, mud, stones.
412. Gravel, shells, mud.
413. Yellow gravel.

SILT COMBINATIONS.

500. Silt.
501. Soft black silt.
502. Hard black silt.
503. Hard blue silt.
504. Blue silt, mud.
505. Brown silt, mud.
506. Silt, mud, shells.
507. Silt, shells.
508. Hard blue silt, shells.
509. Black silt.
510. Soft silt, shells.
511. Silt, mud.
512. Brown silt, hard.

MUD COMBINATIONS.

600. Mud.
601. Black mud.
602. Brown mud.
603. Mud, shells.
604. Soft brown mud.
605. Hard mud.
606. Soft black mud.

STONE OR ROCK COMBINATIONS.

700. Stone.
701. Blue stone.
702. Ledge.

FILLING COMBINATIONS.

800. Filling.
801. Filling, wet.

HARD PAN.

900. Hard pan.

WATER.

999. Water

DISCUSSION.

Mr. Worcester.—Mr. H. A. Carson, on account of pressure of work, has been unable to present a formal discussion of the paper, but has made verbally the following suggestions:

He raises the question whether there is any possibility of the alkaline constituents of cement affecting, in a deleterious manner, wood with which it is in contact, this reason being particularly important where pile heads are imbedded in concrete. He states that he has no evidence of any such injurious action, but, as a precaution against it, it has been his practice for a number of years to treat all wood in contact with concrete with a wax or paraffine paper.

He also suggests that in determining the resistance of soil too much dependence must not be placed upon a test load upon one pile or upon a limited area of earth. The reason for this is that, where a load is placed upon a small extent of surface, the pressure is distributed through the ground upon larger and larger areas as it goes downward, the portion affected being in the form of a cone with the vertex at the top. If, however, the other loads are applied to the immediate vicinity, the cones under each interfere with each other and thereby increase the load on the lower strata of soil over what they were from a single load, and, in case there is softer material below the surface than immediately under the load, it is quite possible that the total sustaining power per square foot would be less where a large area is loaded than would appear from a single test load.

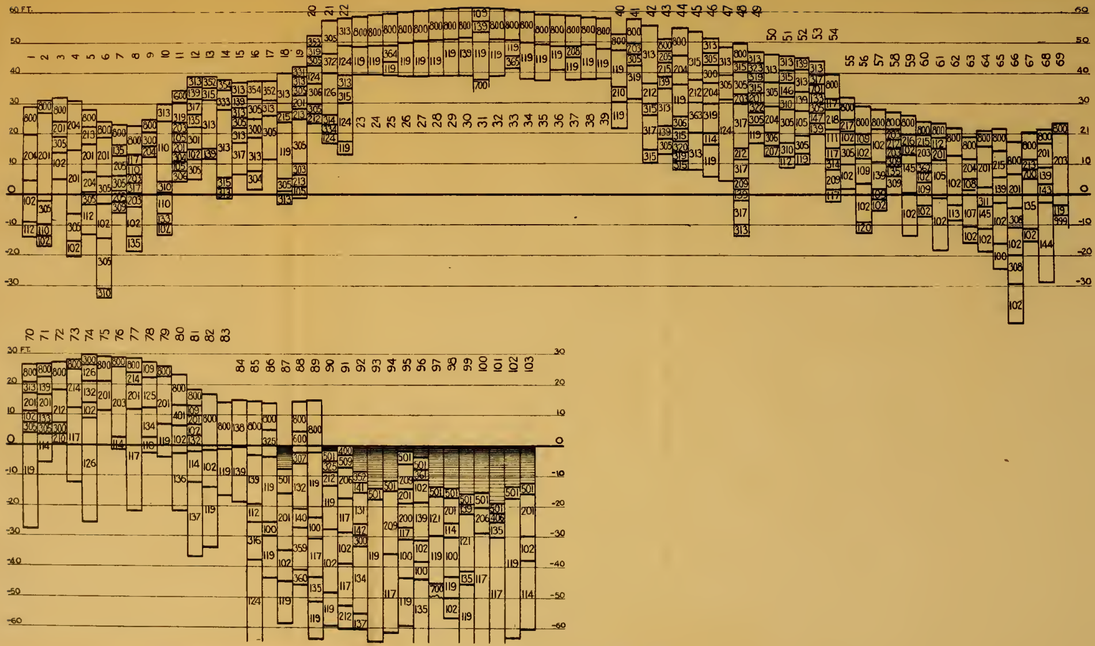
The same results might occur from a test load on a single pile, provided it is held by skin friction.

Mr. John E. Cheney.—I think Mr. Worcester's paper is an interesting, valuable and timely presentation of conditions existing and methods generally obtaining in the construction of building foundations in this vicinity, and the Society is to be congratulated upon its receipt.

In reference to Mr. Worcester's remarks about floors and walls in buildings, which of course have a great deal to do in designing foundations, I would say that when the commission was

MAP OF BOSTON
SHOWING LOCATIONS OF BORINGS

designing foundations, I would say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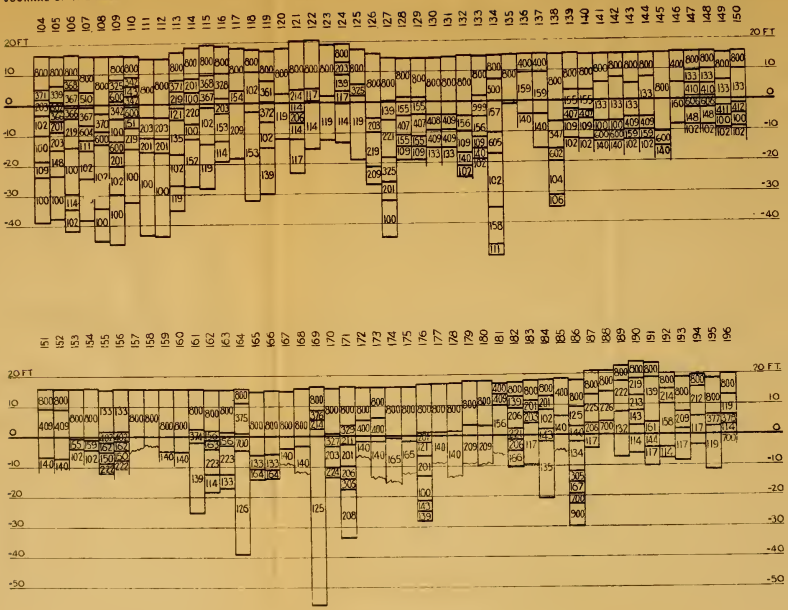

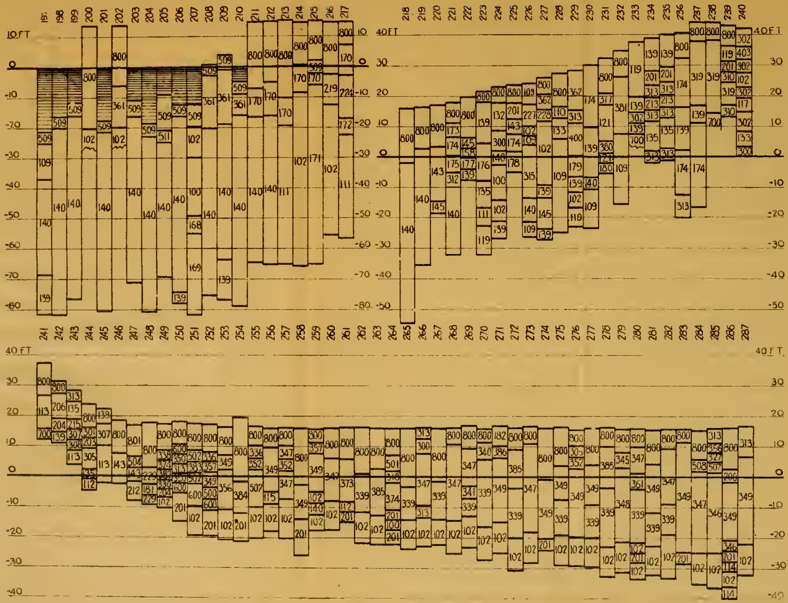

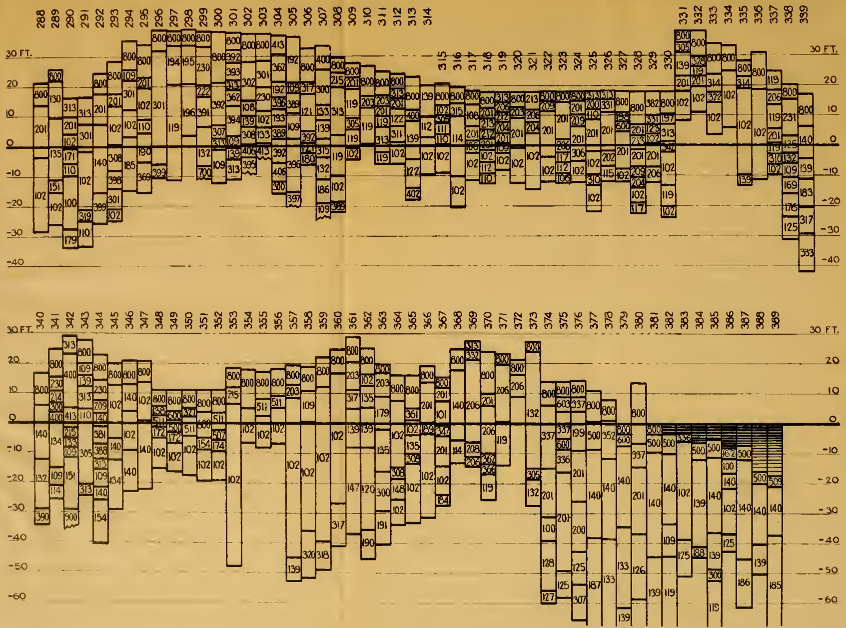
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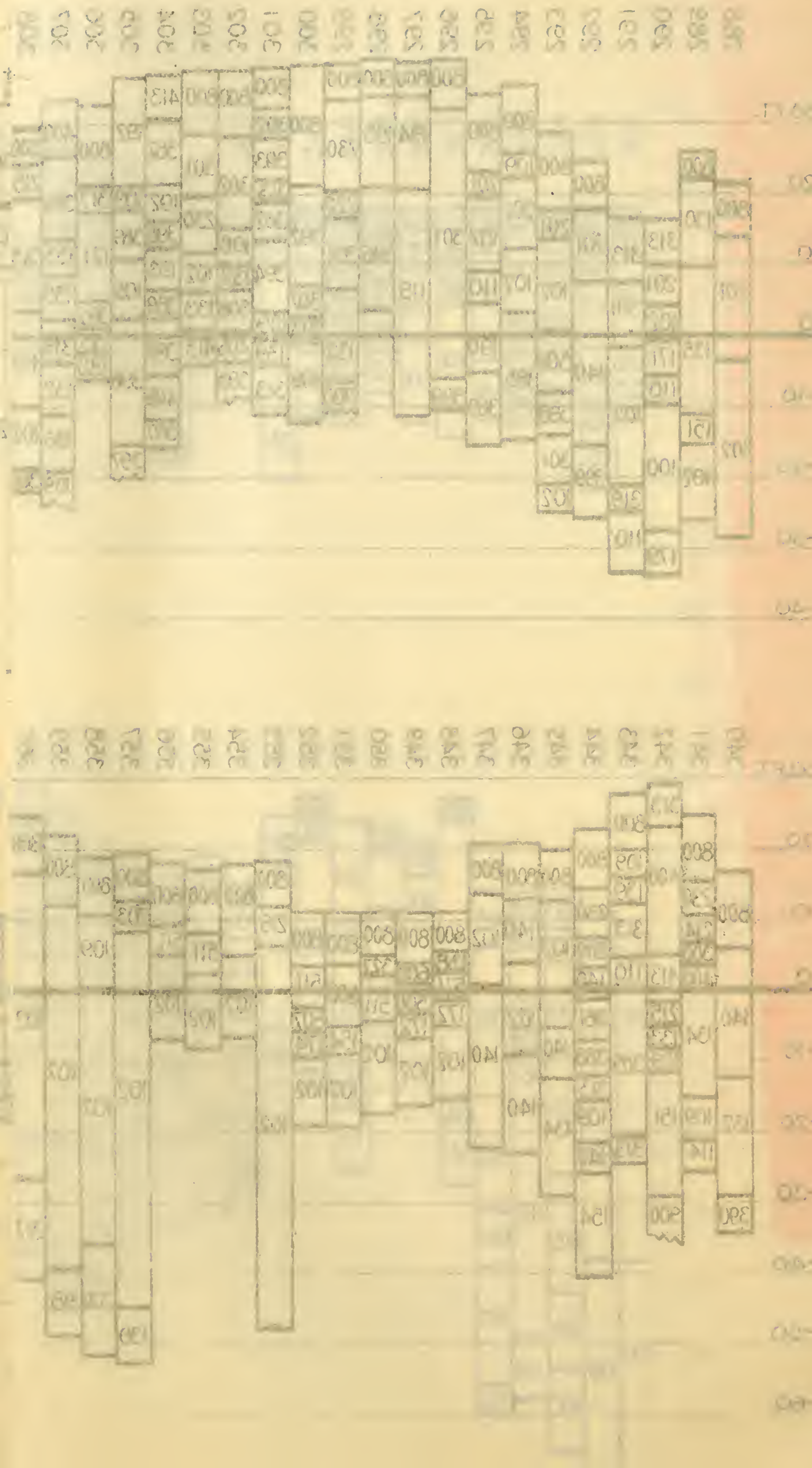
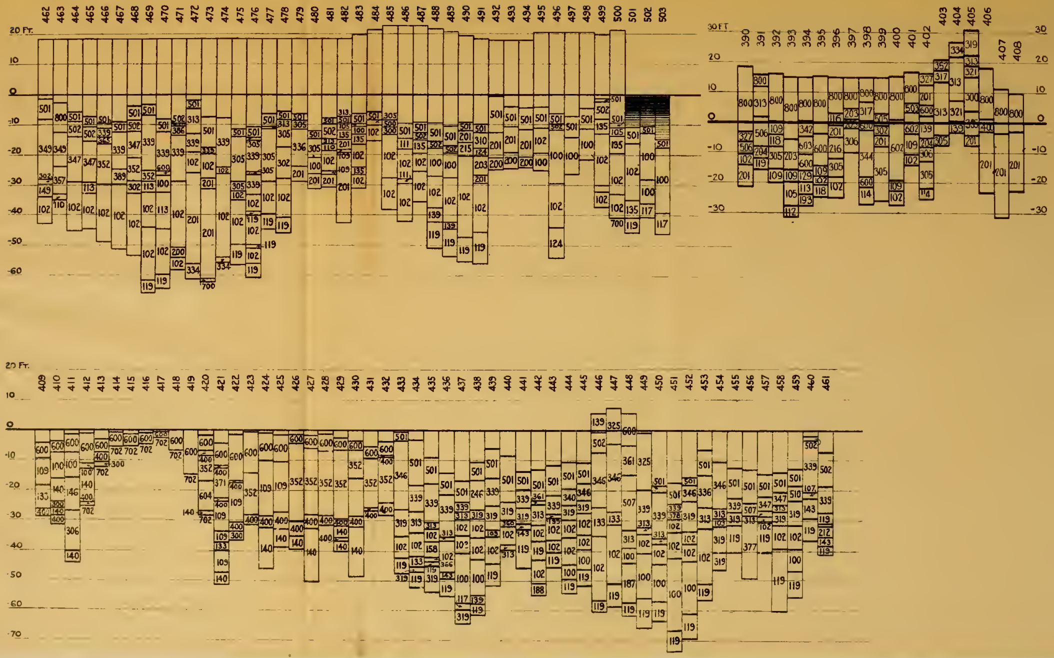
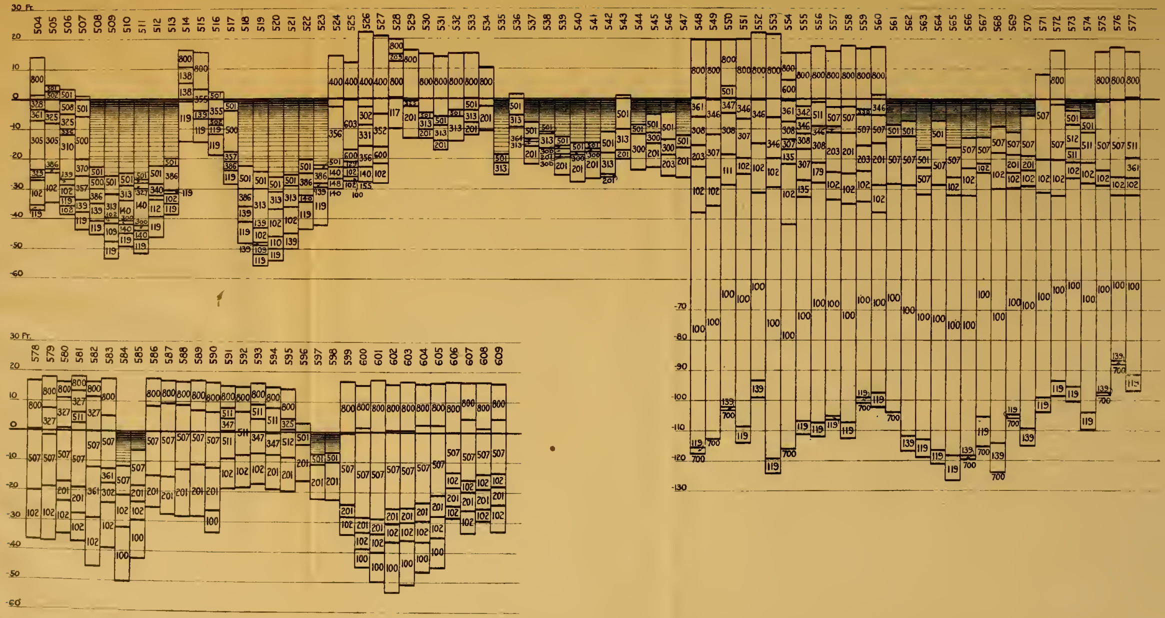






appointed to revise the old building laws and to draft the present building laws I was secured as consulting engineer, but my duties were simply in relation to the unit stresses for materials, which were adopted at the time. I was not consulted about the floor loads. I have thought for quite a number of years that if concerted action could be had by engineers and architects, a great deal of this trouble, of which architects particularly complain, of having to take all the live load on every floor and carry it underground, could be avoided. I know that at one time the Boston Chapter of the Society appointed a committee to consider that, but nothing ever came of it.

Before the present building law was framed, in 1889, when the Exchange Building was built, the total load, dead and live, on beams was taken at 250 pounds to the square foot, while the loads figured upon the walls and columns were figured at 150 pounds per square foot. That means that live load on floor beams was assumed at 150 pounds to provide for local loadings, whereas upon the walls and columns only 50 pounds were provided for use. I think there would not be much trouble in getting the building law—which is really a state statute—amended in the provisions for floor loads and their supports if intelligent efforts were made in this direction. One of the requirements of the present law called for a very excessive load per square foot for dwelling houses, etc., and that has been amended. The building commission has the right to prescribe the loads on floors which have not been provided for in the statute, and in some cases of stables, riding schools and special classes of buildings this has been done.

In regard to the requirements for the diameter of piles, it has been the custom in the Engineering Department of the city of Boston to require them to be at least 6 inches in diameter at the tip and no requirements for any diameter of the pile where the pile is to be cut off after driving, except in cases where the pile is to be capped with timber, but in no case has it been thought necessary in recent years to specify the diameters at the butt and tip. It has been thought that 6 inches tip diameter was as good as any for ordinary foundations, and that a pile with this diameter at the tip would, if it was a long pile, be probably 9, 10 or 11 inches in diameter when cut off. The foundation piles in clusters of more than two rows should be considered as ultimately supported by the material below their tips, and the safe supporting power of this material should be used in determining the area to be piled and the spacing of the piles in the same.

In the case of an isolated pile driven into clay capable of sup-

porting 2 tons per square foot, it is probable that its frictional support will be distributed over quite a horizontal area beyond the material below the tip, but in case several piles are to be driven into the material, and each pile is to carry Mr. Worcester's load of 9 tons, it is evident that it should have at least 4½ square feet bearing area and the piles so spaced as to include not less than this area between their centers. That is in line with the communication of Mr. Carson, carrying out the same idea. The same reasoning should hold good in spacing piles with underlying soils of various supporting powers. Test piles in sand or uncertain material show what those particular piles sustain, but the results obtained should be used intelligently.

In relation to the requirements for driving piles, the Engineering Department of the city of Boston has generally required that piles be driven to a satisfactory bearing or to the satisfaction of the city engineer. In all important foundations accurate borings are made and plotted and either the strata into which the piles should be driven is given or, in the case of frictional piles, the distance that the piles shall be driven into uniform material is given, and it would seem that it would work no hardship upon a contractor if he has all that information given him to make his estimate by. We generally use the *Engineering News'* formula. We don't know that it is any more accurate than any other, but, if we wish to figure up about what a pile might be considered to be good for, for a given weight of hammer, drop and penetration, we use that, and get by it satisfactory approximate results. It is a very simple matter in writing specifications, where it is specified that piles shall be driven to a certain strata or to a certain length, to make provision for payment for additional length of the pile, if required. It has been supposed by a great many that there is an ordinance of the city of Boston requiring piles to be cut off at not higher than grade 5, but this is not so. As Mr. Worcester says, it is an unwritten law that a pile is safe from rot and decay if cut off at grade 5, or about half tide. I think that is true where the soil water or any water coming from the adjacent stratum or the sea can wet it. I don't think, as a general thing, it is safe to go much higher than that.

In case of decay mentioned by Mr. Carson, I never heard of any wood being injured by mortar, except a case in Charlestown some years ago, where the studding of a building was—I don't know as I can say rotted—it was simply shriveled up. It was hardly dry rot; the life of the wood was entirely gone. This was underneath some plastering, and the trouble took place, I think, inside of six months. I never heard that anyone found out just

what the matter was, but it was believed that the lime that was used in the mortar was very poor Nova Scotia lime and that a great deal of it had not been properly slacked.

My idea about the injury to piles capped with concrete would be that if the cement was originally dead—that is, did not contain any free lime—there would be no trouble. In the case of worms that we have about the city here, they do their work generally below low tide. Sometimes they go down to the top of the mud, but they never go under it, and they very rarely work where any air gets to them at all. Therefore, it would seem perfectly safe to cut off piles at grade 5, provided the worm is prevented from getting to the pile. In this case mentioned by Mr. Worcester it would seem that there was water in there and the worm did not know whether it was high water or low water, and he probably stayed there all of the time. In all our practice where piles are likely to have water about them we fill in around the piles so that the worm will not work. I should say that there would be no special reason for cutting off the pile at grade 4 rather than at grade 5, but the worm should not be allowed to get at the pile. Another consideration is that the worm will not work in muddy water; he wants clear, bright water. Generally speaking, all the trouble caused by worms about Boston has been in the lower harbor, where the water is bright and clean.

I think that Mr. Worcester's statement that there can be no better capping for foundation piles than concrete has been borne out by the experience of a great many engineers in Boston, but the kind of concrete used will make a great deal of difference in the result of the work. The commissioners who revised the building laws some years ago had it in mind that it would not be proper to allow concrete to be used indiscriminately by all contractors, and therefore its use must be approved by the Board of Appeal, where not provided for in the building law. Recently the concrete foundation under a large building on Atlantic Avenue was the subject of a great deal of anxiety on the part of the owners of the building. This concrete was more or less exposed to tide water. I never found out what their conclusions were about it, but a large piece of it that was given to me showed, upon analysis, that it had very little cement in it. It seemed to be a local condition, as there was concrete in the immediate vicinity which was very good. The probability is that this particular part of the concrete that was so poor was put in by some careless workman when the superintendent was not present.

Mr. Henry Manley.—I remember distinctly looking into the question of a suitable grade for cutting off piles during the time that Mr. N. Henry Crafts was city engineer. My recollection is that soon after the Building Department was organized, in 1871, the city engineer was asked to advise on this point, and, after investigation, grade 5, city base, was recommended. The law at that time required the building inspector to prescribe not only the height, but to actually give the grade at which piles should be cut, and that is the law and the practice now.

While grade 5 is the standard, the Department may vary its requirements in any or every case in the discretion of the commissioner. The general rule of grade 5 must have been in use for more than thirty years.

Mr. J. Parker Snow.—In capping piles with concrete, the practice on the Boston and Maine Railroad is to fill between the pile heads 1 to 2 feet deep, with the top of the concrete flush with the tops of piles. The reason that we do not build concrete above the pile heads is that, in the necessary hurry to proceed with the work of building masonry when the foundation pit is open to its greatest depth, with pumping going on and the banks liable to cave, it is quite probable that too great a weight will be piled on the green concrete, so that it may be crushed over the pile heads and render the work liable to settle in future. In this case the piles would act as so many punches to crush their way up into the concrete. As stated by the author, there is but little difference in the cost of concrete and stone masonry; hence there is no great advantage in bringing the concrete above the heads of the piles. One or two feet of concrete around the piles below their tops serves all of the good purposes of a larger mass and allows the principal weight of the masonry to come directly on the piles. The good purposes referred to are: tying the piles together, forming a complete filler between the stone work and soil below, and furnishing a proper surface on which to spread a bed of mortar for setting the first course of stone.

If the soil is very soft, it is better to put in a layer of small stone than to deposit the concrete directly on the mud. Only enough stone should be used to fill the mud and make a fair paving on which to start the concrete. It is important that a solid surface be formed, on which to start the first course of stone work. If this is not done, there is great danger that the stones will not get a full bearing on all the piles; while, if such a surface is furnished, a full bed of mortar can be put down and the desired result will be secured.

These remarks apply more particularly to abutment and other

heavy masonry, but they are in line with the subject of the paper and applicable to Boston, as well as elsewhere.

For ordinary building walls and other narrow foundations, the quite common practice of driving two lines of piles $2\frac{1}{2}$ to 3 feet apart on centers and having the piles in pairs—that is, opposite each other in two rows—and capping them with squared stone laid headerwise, one stone on each pair of piles, is to be commended. In my opinion, the secret of good work in this method, is to put the piles far enough apart lengthwise of the wall, so that each stone can be centered on its pair of piles, even though the space between the stones is as great as 6 or 8 inches. It is much better to have the piles centered under the stone than to lay the stones close together and have them come eccentric on the piles. The spaces can be filled with small stone and mortar or with concrete. When laid in this way the stones cannot tip, and each one gets its own bearing and full support on the piles.

Mr. Worcester does not mention crib foundations. Although not much used around Boston, this is a legitimate class of foundations and should be noticed in this discussion. At pier 7 of the Hoosac Tunnel docks and Elevator property, Charlestown, the ground was found to be too hard for driving piles satisfactorily, and it was dredged out to get the necessary water, 30 feet at low tide, and cribs were built, 30 feet square on the bottom and high enough to come above low water. The cribs were built of spruce logs; they were sunk side by side and then faced on the outside with concrete. On top of this crib work and facing was laid a concrete wall to retain the earth filling of the pier. There was some trouble in getting the cribs into place. They were built on launch ways in the Navy Yard and floated into place, but they developed a great tendency to list over when they were floated. It was intended to float them into place before filling and then sink them with stone, but they were so difficult to handle that bottoms were put in the corner pockets and stone was filled in for ballast, after which they were handled without difficulty and put in place without trouble. The concrete facing on the front was only 3 feet thick. It was laid under water behind sheet piling which served as a form, with a special bottom-dumping bucket.

Mr. James W. Rollins, Jr.—I can add nothing to the able presentations of the previous speakers, on technical lines, but some experiences of the last few years may be of interest to some of those present.

Regarding pile driving and the loads to be carried, in practice and according to formulæ:

Some years ago we were building a wharf on the James River, in Virginia, and had to build a trestle approach for it. Piles were driven in sand and gravel, and to a depth and resistance which figured an ultimate load of 60 tons. After a few weeks of service, under an engine load not exceeding 30 tons, the trestle settled. In our judgment, this condition was due to the constant vibration and to the fact that the piles, being under water and in sand or gravel, got something like a water-jet effect.

Since the meeting at which this paper was read, I have heard of a case in Massachusetts where piles were driven to almost a refusal in a mill pond to carry a railroad track, and when the trains were first run over the structure it settled in various places.

The above experiences show that formulæ are not always reliable and that, even when piles are driven into a hard strata, they will not always stand up.

In one of our prominent engineering papers recently, some writer on the question of pile driving referred to a common specification which required piles to be driven to a $\frac{1}{2}$-inch penetration, using a 2000-pound hammer and a fall of 20 feet, as our "grandfather's rule," and ventured the opinion that many piles were ruined by driving under such a rule.

The writer fully agrees with this sentiment, having in very many cases pulled out piles driven for temporary work, where driving was not severe, and found the piles either broken in pieces or the ends broomed up. This applies mainly to spruce or other soft-wood sticks.

On the Cambridge Bridge work we have driven a great many spruce piles for temporary work, to carry derricks and tramways, and most of these piles were driven into a stratum of gravel simply hard enough to hold this temporary work. None of these piles ever settled under the load of a heavy derrick swinging 8-ton stones, but when we pulled these piles out we found that, in a great many cases, the pile was either broken or broomed at the end. We also found that, where piles were driven through a stratum of loose gravel, the material would be packed together by the driving of the pile and would not be displaced vertically, as in the case of clay or soft material.

In a foundation constructed as are the Cambridge Bridge foundations, where the piles are driven in two sets, one set being 2 feet above the bottom of the river, the other set 4 feet above the bottom of the river, and the first set being driven and sawed off before the second set was driven, it was found, where the gravel stratum above referred to was met, that it was practically impossible

to drive the second set of piles. In one instance we struck a pile, which was a very heavy stick, 1100 blows of a steam hammer to drive it 1 foot; and we had to abandon the pile and saw it off at the proper level. This difficulty was overcome by dredging out the gravel, which in places was 10 feet thick, then driving the piles, some of which went down to 70, and, after the piles were driven, refilling the areas with gravel to the original bottom of the river. This plan seems to have been a most excellent one, for, had the engineers insisted on our trying to drive the second set of piles through this stratum of gravel, they never could have been driven to the depths to which they ought to go, but by dredging this out and then driving the piles the engineers have absolute certainty as to where the foundation is.

Regarding the supporting power of piles driven in clay or mud, where stability is dependent entirely upon their frictional resistance, in stiff clay a penetration of 20 feet is generally taken to be sufficient to carry a load of 10 or 12 tons. If the weight necessary to settle a pile in clay or mud is proportional to the power it takes to pull them out, their safe load can be placed far above the limit mentioned above. We are constantly pulling piles, most of them having been driven for temporary work, and it is the exception, rather than the rule, that the pile comes up without breaking; and we have not an idea that a pile, driven 20 feet into clay and allowed to stand for a few days, can be pulled by the most powerful tackle in use. We use a 200-ton lighter and a six-block purchase, with results mentioned, and we frequently pull the lighter down to the water's edge and let it hold there for an hour or two in order to even start some of these temporary piles.

Another condition, which all pile-driving formulæ leave out of consideration, is the size of the pile itself in its middle section, they giving no greater supporting power to a thick, heavy stick than to a slim one having the same area of point. In driving piles into clay bottom, where no hard material was met and where the load on the pile was to be sustained by friction alone, we have driven a pile 20 feet by the dead weight alone of a steam hammer and attachments weighing possibly 8 tons. The piles so driven are slim, straight sticks, with a true taper from top to bottom. In the same driving, using a heavy, stock stick, with the same point, it would require some 15 or 20 blows of the same apparatus to drive it an equal depth.

The question of deep foundations, which Mr. Snow has touched upon, is one which has interested us, because in the last

few years we have had a great many to build and under a large variety of plans.

At Bridgeport, Conn., we have just finished some fifteen piers for a four-track railroad, where the bottom was soft mud down to a depth of 35 to 40 feet below low water, and at that depth a very hard stratum was found, so hard, in fact, that the engineers did not dare to drive a pile into it more than far enough to hold the end of the stick. The plan adopted for this work was to drive the piles down to this hard bottom, saw them off exactly by saw-machine at an elevation some 12 or 14 feet below low water, then sinking water-tight caissons onto these pile heads and build the masonry in these caissons, whose sides were detached after the masonry was finished above high water. This plan, of course, left the piers practically on stilts, and stability was assured by depositing rip-rap around the piers on all sides.

The pile driving for this work was rather a novelty, inasmuch as the driving of the piles through the soft stratum mentioned was merely the act of putting them under the steam hammer and attachments weighing 10 tons, the lowering of which weight shoved the pile down to the hard bottom practically without striking any blows. In one day, on this work, 230 piles were driven and 800 piles were driven in three and one-half days.

At Providence, R. I., we have just finished a draw-pier and abutments for a double-track railroad bridge. One abutment went down to grade 20, and this was built in a cofferdam on piles, the cofferdam being pumped dry for the work. For the draw-pier the piles were driven and sawed off at grade 22, an 8-inch cofferdam was built around pier and concrete was deposited in the cofferdam for a depth of about 6 feet. The cofferdam was then pumped out and the masonry laid in the air.

At Quincy, Mass., we built a draw-pier down to grade 24. This pier was founded on piles sawed off at grade 20. A circular crib was built out of short sections of plank spiked together and sunk in position. Concrete was then deposited under water in this crib up to low-water mark; then forms were built for the section from low-water mark to about grade 16 and filled with concrete on tide work.

At Quincy and at Providence the concrete was deposited in buckets, and you are probably all familiar with the work on the Cambridge Bridge, where ten piers have been built. These piers have required some 60,000 cubic yards of concrete, and all of that below grade 4 has been put in through chutes, and, we think, with very satisfactory results.

At Bangor, Me., last spring, we built a pier for the Maine Central Railroad Company in the middle of the Penobscot River, to replace one washed out by the ice and floods. The old plans of this bridge showed rock at about 14 feet below low water, and the plan was to dredge out the overlying gravel and build a crib of timber about 70 x 20 feet in size, sink this into place and then fill with concrete. A little incident in this connection showed further uncertainties of pile driving. To carry the trains across the "washout" a trestle was driven, using very long, heavy piles, and these piles were driven to a refusal and supposedly to the ledge. After we had been dredging for some few days to clear the gravel off the ledge, the trestle commenced to settle, and a diver soon discovered that we had undermined the piles. An emergency call was rung in for the pile-driving gang; they drove the piles 15 feet deeper than the ledge elevation which the plans called for, and it developed that the ledge which the original piles struck was nothing but a nest of big boulders. Under this new condition bottom was dredged to 22, and the crib sunk into place and filled with concrete up to low water. The cofferdam having been built on top of the crib before it was sunk, the masonry above low water was laid in the air, the cofferdam being kept dry, except at high water. Tides at Bangor vary 16 feet, and, consequently, part of this work was done through 38 feet of water.

At Portland we had a proposition involving the building of a pier in the middle of a small river, where we met with some entirely new and unpleasant features in concrete construction. We drove piles and sawed them off at an elevation of 10 feet below the general level of the river; then built a bottomless crib, floated it into position over the piles and sunk it; then, filling the crib to the proper level with concrete, deposited in the same buckets we had been using for several years in this class of work. Two weeks after the concrete was deposited we pumped the cofferdam out and found the concrete had not set at all and was so soft that it could be almost shoveled up. We at once began an investigation as to conditions. We were using Lehigh cement and crushed stone and a very excellent quality of sand, and were consequently assured that the ingredients of the concrete were all right. The engineers and inspectors said that the concrete was mixed thoroughly and deposited satisfactorily, so we were forced to the conclusion that the trouble must be with the river water. We found that there was a pulp mill a short distance up the river, and naturally inferred that some of its waste matter was polluting the stream to such an extent as to prevent the setting of cement. We got samples of all

the cements we could find in Portland,—seven brands,—made briquettes and put them in the river water to harden. This was done in the afternoon or early evening, and the next morning we found that six of the seven briquettes had entirely dissolved and that the seventh was Lehigh cement. The chemical test of the water, however, did not show any impurities, and again we were at sea in our conclusions; but, on talking with the mill people, they informed us that some days they would discharge nothing into the river and on other days would discharge a great deal of waste matter which contained sulphuric acid. A continued set of experiments has shown that the impurities of this water will very seriously retard the setting of cement, but that ultimately it sets up all right. A recent test of a quick-setting cement, which in concrete set perfectly hard in air in twelve hours, showed that it would not set in this river water in seven days. The chemist who made the analysis for us stated at the time that probably the concrete would set all right if we left it alone long enough, and we have found that, after three months' waiting, most of it has set up in a satisfactory condition.

We trust this experience may be of benefit to some of the members, and that, before they put any concrete under water in rivers liable to pollution, they will examine the conditions thoroughly and so save some poor contractor a lot of trouble.

We have heard an explanation of the failure of the concrete on the Atlantic Avenue work mentioned by Mr. Cheney, the explanation given us being that, adjacent to this work, chemicals were discharged into the harbor, and that at high tide they came in contact with this concrete. But this is hearsay on our part, and we cannot vouch for its correctness.

Other cases have come to our attention where the same trouble has arisen, concrete being disintegrated and not setting up properly and the trouble being found due to the water.

As regards the Portland work, at this date (April 1st) we have taken out most of the concrete deposited in the pier, and the engineers now propose to replace it with concrete deposited with a cofferdam pumped out.

Mr. Robert B. Davis, Member American Society of Civil Engineers.—Being somewhat of a stranger in Boston, I am very much surprised to learn that your building laws prohibit the use of concrete grillage on piles for foundations. In this respect they differ from the building laws of many of our most prominent cities. I am confident that concrete grillage on piles is far superior to what you call the granite block system. To bear me out in this

opinion, it is the best practice to-day, not only in other cities, but here in Boston. The objection of the Building Department, as I understand from the paper read to-night, that unscrupulous contractors might substitute an inferior grade of concrete for this purpose, I think would be very easily overcome by the building laws specifying what the concrete should be—the composition of it—and having their inspector see that the requirements were lived up to. Concrete is not an experiment to-day, and I think the influence of a body of men like this Society should be brought to bear on the proper parties to have such law revised so that we could use proper concrete grillage on pile foundations.

There is just one other point I would like to mention, in relation to some of the formulæ for pile driving. There is no question that serious objection to many of them is due to the fact that they overlook considerations of great value; for instance, loss of energy due to the brooming of the point of the pile, the variation in the frictional resistance on the superficial surface of the pile and the depth of the pile in the soil. Personally, with my experience in such work, I do not see how a formula that gives simply the factors of weight of hammer, height of fall and penetration of last blow can give a satisfactory conclusion either as to the immediate or ultimate holding power of the piles. After a period of rest it almost goes without question that the supporting power of the pile is due to the upward force of the material under the point of the pile and the frictional resistance on the superficial area of the pile in contact with the soil. I have made use of a formula suggested by W. M. Patton in his "Practical Treatise on Foundations," probably well known to the members of the Society, although not seen in print as often as others. It reads as follows:

$$S = \frac{W - P}{F}$$

S is the number of square feet of the surface of the pile in contact with the soil.

W is the load on the pile.

P is the bearing power of the soil, or resistance to settlement.

F is the resistance or friction of the soil on the superficial area of the pile.

If we have P and F we can then obtain just what we want. P and F we get from experiments and experience, just as we obtain constants for steel columns, beams, girders and timbers. We find in good practice that P will vary from 5000 to 6000 pounds per square foot for dry sand or gravel and it will equal zero for silt. F will vary from 100 to 300 pounds per square foot for soft semi-

fluid soils, from 300 to 500 pounds per square foot for mixed earths and gritty soils and from 400 to 600 pounds per square foot for compact clays, sand and gravel. You ask where we get these results; they are determined by experiments and experience. If we take any reasonable values for P and F; this formula is as good as any of the other formulæ used. It is more reliable than many, as it takes into consideration the actual conditions that we meet in each particular case. It gives us a fair standard of comparison, as now exists in the case of steel columns, beams, girders, timbers, etc., which are all based on constants arrived at by practical experiments. It appeals very strongly to me because it is based on results of actual experiment.

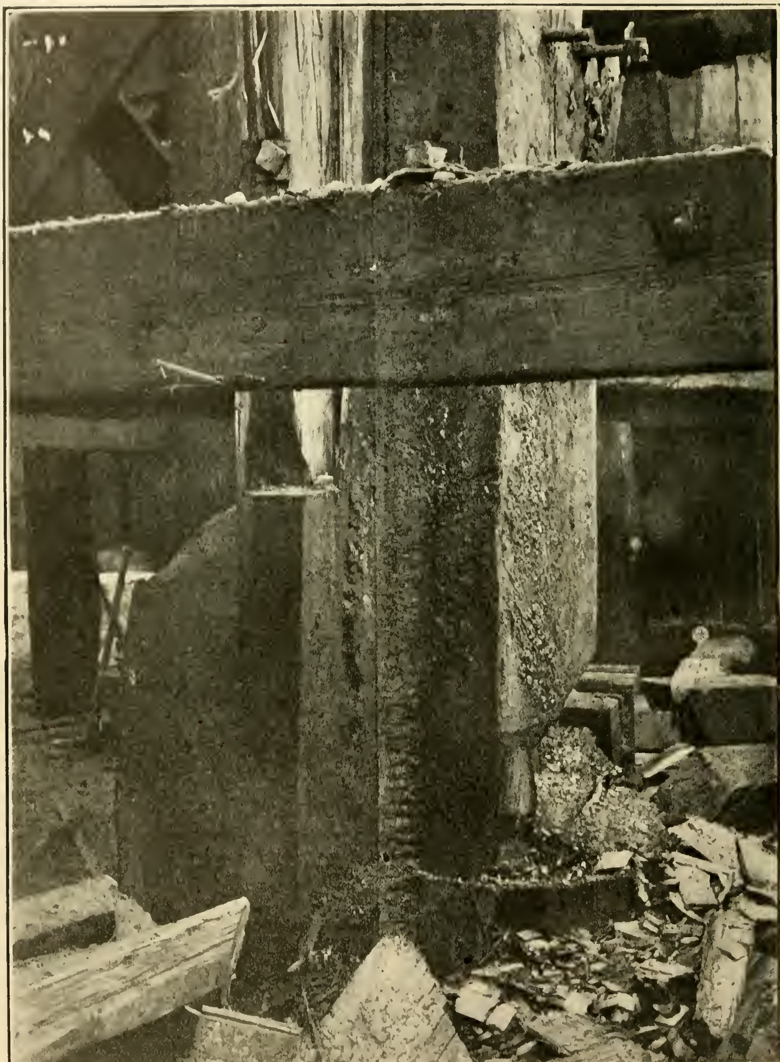
Mr. H. K. Higgins.—Mention has been made of the Electric Light Building on Summer Street, of which I sent a photograph to the *Engineering News*. Of the two accompanying photographs, one shows the appearance of these piles after the foundation was taken off. I can readily believe that worms, rather than decay, may have been the cause of the difficulty.

The other photograph shows the interior of a Cushing process pier, which was taken out for us at Providence. We cut the Cushing piers down 10 to 12 feet below low water and built them into the new 40-foot diameter draw pier, they forming a part of the foundation. The timber, which had been forty years in this pier, was, when we took the casing off and removed the concrete, as good and bright as if it had been put in yesterday, excepting that the iron bolts had rusted in places to some slight extent. In fact, the timber was superior to what we can get at present.

The question of loading, which Mr. Worcester has mentioned, came up in something of an aggravated form in connection with the design of the Summer Street Bridge foundation in South Boston, and, as I remember it, we finally concluded to reduce the assumed load. We had 300 pounds to the square foot of bridge. If the foundation was to carry all that, it would have to be considerably heavier than most engineers would want to put in, so we finally reduced the load to about 250 pounds; 200 of that was dead load and the other 50 live load. That is on the same principle as applied to the column loads by Mr. Worcester.

Speaking of preservative processes as applied to piles, we have had some difficulty in connection with very long piles which we have put in a fender pier in a city a little way from Boston. The conditions were nearly the same which we would have had in a draw pier in the Fort Point Channel if the New England Bridge had been rebuilt, but more complicated by great depth of water and

Pile Foundation near Summer Street, Boston, after Thirteen Years' Use.



Interior of "Cushing" Pier, at India Point, Providence; Built 1862; Uncovered 1892.

mud. The piles are some 50 feet out of the mud; the mud is very deep; it is impossible to get a pile of sufficient length to get any kind of bearing. We took the alternative of splicing the piles. The upper pile is made of good timber treated with creosote, extending 10 feet into the mud. The lower pile extends some 40 feet below that, is spliced to the upper pile and is not treated, depending upon the mud to keep it in proper condition.

It seems to me that there can be no hard-and-fast rule for cutting off piles, because the condition of the ground water is so variable. In Dorchester there were a number of deep wells near certain streets. The city built an intercepting sewer, or a part of the main drainage sewer, through that section, and all the wells immediately ran dry. They have had no water in them from that day to this. This indicates that the ground water level has been permanently lowered. If I were designing a pile foundation I would find out where the ground water was and what changes were probable; then cut the pile heads to or below that point, whether it was low water or grade 50.

Mr. Sidney Smith.—About twenty-eight years ago, when they were building the Sudbury River conduit, there was a case of the apparent failure of concrete somewhat similar to that mentioned by Mr. Rollins. At one of the bridge foundations the very efficient inspector condemned the concrete at the end of the first week. However, the engineer in charge, Mr. Alphonse Fteley, had confidence that the contractors had done good work, that the inspector had properly performed his duty, that the cement was good and that the only element lacking was time.

The contractor was very anxious to lay stone upon it, but he did not choose to pump from the gravelly soil in the vicinity of Charles River to keep it dry and thereby expedite the setting of the concrete. The water was pumped out weekly. My recollection is that, at the end of the third week, you could have run the whole length of the blade of a pocket knife into the concrete. At the fourth week, the concrete then having become completely hardened, they were allowed to proceed with the masonry. I think the cement was imported German. We did not have the improved American cements at that time.

In some cases, if the concrete is well placed and not disturbed, the setting of concrete under water is simply a question of giving it more time.

Mr. Percy C. Barney.—I have a few suggestions growing out of our experience at the Navy Yard. We have used all of the four kinds of foundations described by the author: piles held by skin

friction, piles supported on strata of very hard gravel, foundations supported on earth and, lastly, the crib foundation. All are very satisfactory, with the exception of a few cases. There are two points about the crib foundation which I think need careful attention, (1) that of alignment, (2) that of back filling afterward to prevent the crib from sliding. I would not use a crib foundation for any permanent improvement unless the cribs could be built a long time before the improvement, as in the Buffalo Breakwater, where the cribs were built some years ago, and where recently a concrete sea wall was built on top of them. We usually limit the safe load on the soil to 2 tons per square foot. At one place we were unable to examine the ground before letting the contract, and designed it for 2 tons per square foot. When we came to build we had to change the foundation so that the load was about 1 ton per square foot, and the foundation is still unsatisfactory.

We use the *Engineering News'* formula for all work, and we have been very well satisfied with it. It is used in a number of the United States navy yards.

As to the point of cutting off piles, I have had occasion to examine that carefully, and I have found, almost without exception, that piles driven in earth and cut off half way between mean high and mean low water, and in some cases above that, have been perfectly sound. Recently, in tearing out an old pile foundation where the mud was about 6 feet above mean low water, I found the piles perfectly sound from 1 to 2 feet above the mud. These piles had been in the ground seventy-five years.

In making borings for the dry dock we found rock at from 80 to 100 feet below mean low water.

Mr. Geo. B. Francis (by letter).—In regard to foundations in Boston, my experience is confined to the foundations under the South Terminal Station.

This was located, throughout the entire site, on an area that was originally flooded by salt water, and, consequently, was piled, there being 43,816 piles used altogether. It was friction ground, although, over a large part of the area, the piling penetrated to a sand, gravel and clay stratum. There were some places where the piles would go nearly a foot at the last blow of the hammer, and in such places a considerable number of extra piles were driven. The footings were all of concrete, deposited around and over the heads of the piles. Owing to the language of the legislative act under which this station was constructed, it was claimed that the city Building Department had no jurisdiction and the city building laws did not apply. As a matter of fact, probably no such structure as

a large train shed, together with the accompanying retaining walls, etc., was in the minds of the framers of the city building law, and the construction is really better than would be conceived by the framers of such a law.

The Hotel Essex, which is on the opposite side of Atlantic Avenue from the station, at the corner of Essex Street, is founded upon the natural earth, there being no piles used in its foundations. It would seem singular that such would be the difference in the foundation of these two adjacent structures if it were not made clear that the hotel is on an area not flowed by salt water; or, to speak correctly, it is on the extreme end of what was known in early history as Wind Mill Point, as will be seen in the plan showing the old foundations on the South Terminal site.

In regard to the piles under the old Electric Light Station on Summer Street, opposite the South Terminal Station, I am glad to learn from Mr. Worcester's paper that the decay around the heads was due, not to rot, but to worms, as I have always had doubts about the correctness of the first theory advanced and published.

From my experience in Boston, I believe that elevation 5 is low enough to cut off piles and to keep them submerged sufficiently for their protection when the piles are wholly imbedded in the earth. The ground water, within a short distance from the harbor, at the Terminal Station stood at elevation 9, and did not ebb and flow with the tide.

President Kimball.—I understand that, in building the East Boston Tunnel on Court Street, where it passes the Ames Building, under the direction of Mr. Carson, some concrete sheet piling has been driven, some that it was necessary to leave in place, and I will ask Mr. MacCurdy to speak about this work.

Mr. H. S. R. MacCurdy.—The excavation for the East Boston Tunnel, in Court Street, passed within 1 or 2 feet of, and from 6 to 8 feet below, the foundations of the Ames Building. This building is not a steel framework structure, but the walls are of solid masonry, and numerous cracks which had appeared in the face of the building suggested a possibility that the material under the foundations was not especially firm.

The work on the tunnel in that vicinity was done by day labor, so that the engineers could have complete control and could from time to time make such changes in the plans as seemed advisable.

The excavation was in clay, and in sand containing some water, and was carried on by the slice method. Trenches, 16 feet long, separated by a core of earth 16 feet long, were carried down to

about the level of the bottom of the foundation of the building, when one-half of each trench, or 8 feet, was excavated to grade.

The bank was held in place by means of concrete sheeting, composed of slabs of concrete from 6 to 8 feet long, 6 inches wide and 2 inches thick, in which were imbedded $\frac{1}{2}$-inch square corrugated steel rods, running the entire length of the slabs. The concrete was composed of two parts of crushed stone dust to one part of Portland cement. If wooden sheeting had been used, it would have been necessary either to concrete directly against it and to have left it in place, or to have pulled the planks as the concrete came up. If the first method had been used, being above ground-water level, the sheeting would in time have rotted, causing a void, to be eventually filled by the compressed material under the building foundation; while, if the planks had been pulled, there would have been danger of losing ground through the carelessness of the workmen. Both of these difficulties were, of course, entirely eliminated by the use of concrete sheeting.

The method used in driving the sheeting was one that first suggested itself, and it proved to be the simplest and most effective. One man would hold a follower, made of a piece of soft wood about 6 inches square and 3 or 4 feet long, which another man would drive with a maul.

The bottom of the excavation was kept about level with the bottom of the sheeting. In order to guard against any voids, which might have been left behind the slabs in driving, grout was poured into holes made by driving an iron rod at intervals close behind the sheeting. This sheeting served a double purpose. It not only held the bank in place till the concrete wall was built against it, but was also coated with waterproofing and served in place of a back wall. As the sheeting was not disturbed, from the time it was driven, and as the concrete wall of the subway was built directly against it, there was absolutely no danger of losing ground or of thereby causing settlement and injury to the building. About two hundred of the concrete slabs were used in this work, and in no case were any of them chipped or broken.

Mr. H. S. Adams.—It is getting so late that I will only say a word, and that is in regard to the methods used for testing ground where piles are to be driven. It is generally done by means of borings. Perhaps some of you will remember when the old iron punch rods were driven down into the clay to test the ground. My experience in clay has been that when two good, smart men have driven the rod down to resistance, it is safe to estimate that a pile, driven 10 or 15 feet farther than the rod went, will give a

good foundation. The method seems to me a good one, and gives about the same results as Mr. Worcester arrives at in his formula. Mr. Worcester's formula agrees well with the practice that I have had. We cannot expect, down in the clay, to get quite as good results as shown by published formulæ and rules, nor can we get as great resistance as is called for by them, but we get fairly good results.

In listening to the paper read this evening describing a coal pocket at Lincoln Wharf,* I was interested to note that the engineer designed the piles to hold 12 tons each, exactly the same load as I allowed for the piles in Union Wharf, which adjoins it. These piles are spaced 6 x 8 feet on centers. After Union Wharf was constructed, and during the time the coal pocket was being put on Lincoln Wharf, Union Wharf was loaded a little over a ton to the square foot, bringing a weight of about 48 tons on a pile. We could not find that the wharf had settled any. We used 50 and 55-foot piles, with about the same penetration as the piles at Lincoln Wharf.

Mr. L. M. Hastings.—In the matter of foundations requiring piles, unless the soil is soft and plastic, I should question the desirability of driving piles as near as 2 feet apart on centers. From my own experience, I think 2 feet 6 inches is as near as is safe to place piles in ordinary soils—sand, gravel and the like. With closer spacing we incur danger of loosening and displacement in driving and of losing some of the full bearing power of the soil. It is better to spread the foundation, if possible, to obtain the requisite number of piles to carry the load. With regard to driving in hard soils, it is far better to reduce the fall and increase the weight of hammer. A fall of 6 or 8 feet, with a 2500-pound hammer, with blows delivered as rapidly as the hammer can possibly be raised, will accomplish more and leave the pile—if of spruce or other soft wood—in far better shape than if driven with a long drop and light hammer. This is the great advantage the steam hammer has over the ordinary style of pile driver, it being possible with this to drive piles, sheeting, etc., in soils where, without the water jet, it would be impossible.

When the penetration has reached a small amount, say $\frac{1}{4}$ inch to $\frac{3}{8}$ inch per blow, and the hammer rebounds considerably, it is pretty safe to conclude that the limit of safe driving on that pile has been reached. Further driving should be done with great care; otherwise "brooming" of the end of the pile or fracture of the pile will occur and the pile be ruined.

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*See Journal of the Association of Engineering Societies, March, 1903.

The elements in determining the bearing power of a pile, when driven, are so variable and uncertain that I doubt whether any of the formulæ are of much value for universal application.

It is here that the skill and judgment of the engineer, based on experience, should be applied to each case as the conditions are observed, as the work proceeds, and the length of pile and amount of driving should be varied with these observed conditions.

If the pile is driven so that the last penetration does not exceed 1 inch with a 10-foot fall of a 2000-pound hammer, a load of 9 or 10 tons may usually be considered as safe for the pile.

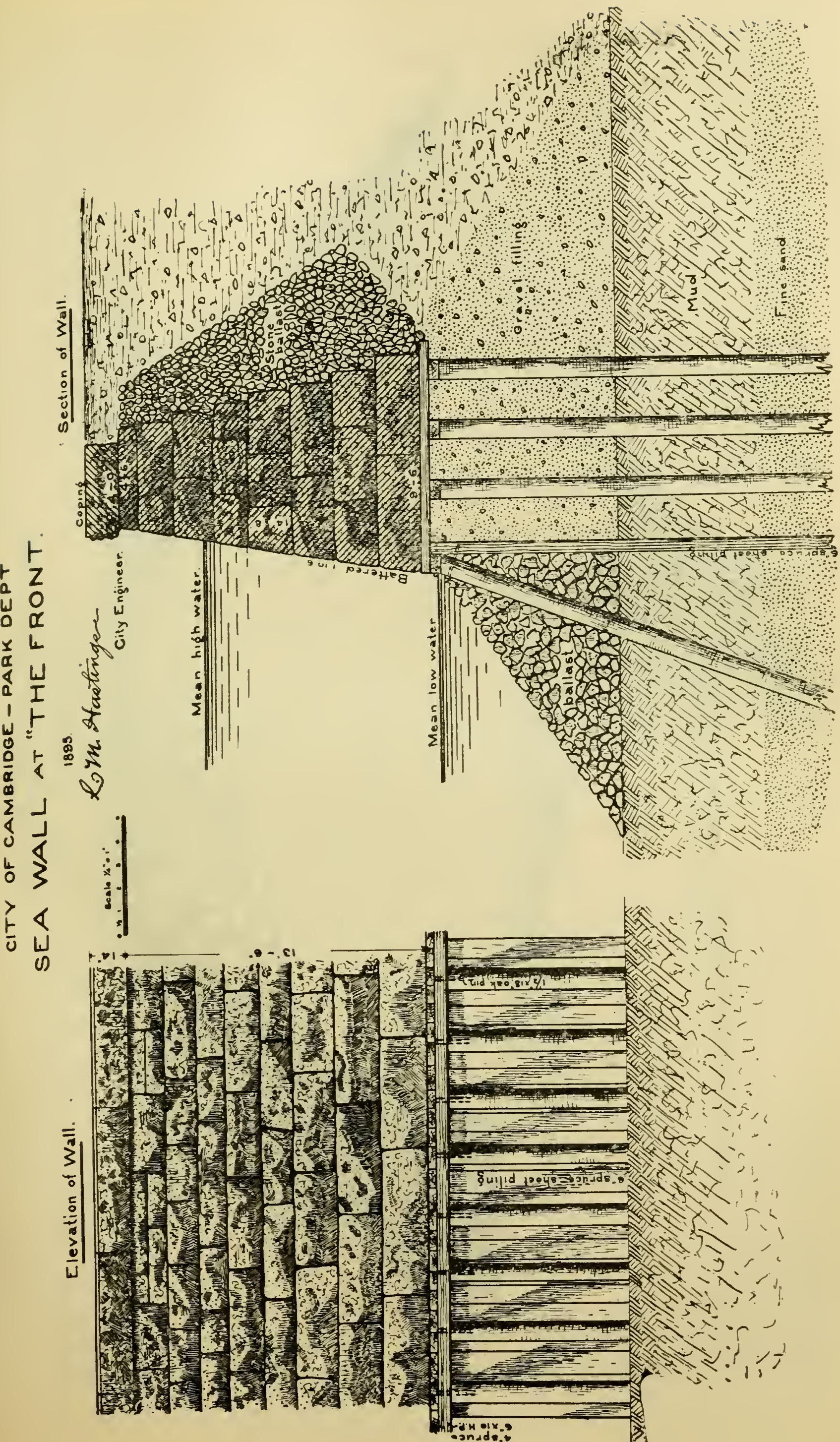
With regard to cutting off piles, the proper elevation must evidently vary with the locality and the elevation of the water table in the ground.

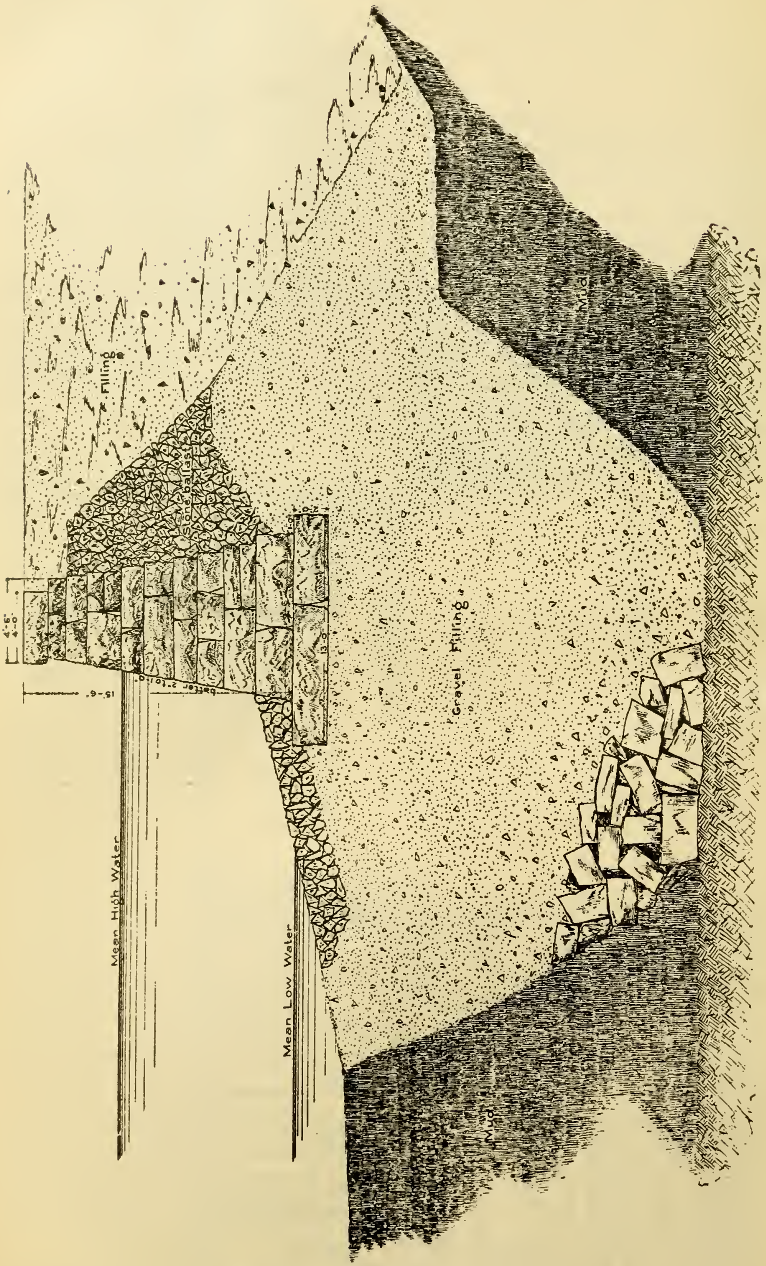
Unless the land is low, this will seldom be found permanently above the water line in the sewer in the adjacent street, especially if the soil is of a porous character. In Cambridge this is often taken as a proper and safe grade at which to cut foundation piles. Even in low ground the presence of a neighboring sewer may keep the ground-water level at a lower elevation than would naturally be the case.

For sea walls piles often form an important part of the foundations required. The accompanying figures show the different treatments given in two rather interesting cases.

In the first, hard bottom of compact sand was found about 6 to 14 feet below the grade at which it was possible to place the timber platform upon which the wall was built. Above this sand was about 6 feet of soft mud. Filling was to be placed behind the wall to a depth, in places, of 20 feet. Of course, the tendency would be for this load of filling to crowd the mud into the river between the piles, and also to force the wall forward out of line. Three rows of piles were driven to take the middle and rear portion of the wall. Near the front or toe of the wall a line of 6-inch hard pine sheeting, tongued and grooved, was driven. In front of this and firmly bolted to the sheeting was driven a row of heavy spruce inclined or "spur shore" piles, driven about 20 to 23 degrees from the vertical. The whole was then covered with a heavy timber platform. The whole cost of the foundation was $3.01 per linear foot. Although the filling has been placed behind much of the wall and some of it heavily loaded with stone, little or no movement of the wall has taken place.

In the other case for a short distance the hard bottom was found some 24 feet below mean low water. As the rest of this wall was founded upon a gravel foundation of only shallow depth, it


CITY OF CAMBRIDGE – PARK DEP'T
SEA WALL AT "THE FRONT."
1885.
L. M. Hastings
City Engineer.
Section of Wall.
Coping
Stone ballast
Gravel filling
Mud
Fine sand
Mean high water.
Mean low water
Battered line
ballast
6" spruce sheet piling
Elevation of Wall.
13'-6"
6" spruce sheet piling



SEA WALL ON CHARLES RIVER (1897).

was not thought best to insert a short section founded on piles; besides, owing to the great depth, an adequate pile foundation would have been very expensive. Instead, therefore, a wide trench was excavated in the mud to the hard bottom and then refilled with gravel dredged from the river. Stone from an old sea wall was also dumped in the trench as the filling proceeded. The wall was partly laid in the fall, left over winter and completed in the following spring. The foundation courses settled about 18 inches after it was laid. The coping settled from 3 to 5 inches since it was laid, some six years ago, but so gradually as not to be perceptible.

There are numerous cases in this city of buildings built on mud of considerable depth, having a foundation resting on a timber platform, "floated," as it is called. If the mud is of uniform depth and the weight of the building evenly distributed, any settlement occurring is so uniform as to do no harm and is seldom apparent to observation.

In capping piles for sewer, sea wall and similar construction it is best to use hard pine timber, as much better able to resist the crushing force encountered in carrying the heavy weights. For this reason it is best to use as large-sized piles as possible, always cutting the points, rather than the butts, as much as possible. One scarcely realizes the tremendous force oftentimes exerted upon a foundation, until after having examined its effect in crushed and broken timber in an old foundation being removed.

In buildings I am strongly in favor of, and always recommend, a layer or footing course of concrete for foundations for heavy buildings, whether piles are driven or not.

Its cheapness and the ease with which it can be placed, and, above all, the *uniform surface it presents to the supporting soil,* are very strong points in its favor as a first course in a foundation, whether the soil may be good or bad. With a layer of good concrete 3 feet or more thick, well rammed over the full width of the trench (and if piles are driven, in and around them), I believe the best possible beginning for a good foundation has been made.

Mr. Edward W. Howe.—The subject of inclined piles having been introduced, the following method, used in building the foundations for the new Atlantic Avenue Bridge across Fort Point Channel, may be of interest:

The space was so cramped and the current so strong that it was impossible to drive the piles in the ordinary way, by laying the scow in line of the inclination of the piles and tipping the gins back to the required angle. The piles were driven in water of a depth of 20 to 30 feet and the tops left in that depth. The con-

tractor constructed a tube or chute. This was composed of four angle irons latticed together, forming a square tube, open on the sides and smooth on the inside and 14 inches square in the clear. It was made in sections of from 5 to 20 feet in length, which had flanges on the outside by which they could be bolted together. The top section was flared, forming a sort of hopper, of a width which allowed it to be placed freely in the gins of the pile driver, lugs on the outside at the top serving to hold it in place. The tube was supported vertically by a rope running over a sheave at the top of the gins beside the sheave holding the hammer rope.

The method of using the apparatus was as follows: Ranges having been set showing the position of the pile where it was to enter the bottom, the chute, supported free of the bottom, was placed on line and dropped on to the bottom. The pile was then raised and dropped into the chute, and by its rebound as it struck the water the chain attached was released, leaving the pile floating inside of the chute. The top of the chute was secured in the gins and the scow moved until the inclination of the chute had the required angle and direction. The hammer, a block of iron 8 feet long and 13¼ inches square in section, and with a ring at the top to which the rope was attached, was then lowered into the chute and the pile driven to grade.

This method insured the pile being in the correct position and having the right inclination, conditions which it is difficult to secure in deep water with a strong current when working from a floating scow held by lines extending horizontally to fixed objects.

The apparatus worked very satisfactorily, also, in driving vertical piles, as many as ninety-five having been driven in nine hours, the piles being 33 feet long, driven to a grade 50 feet below mean low water.

The contractor who employed this method was Mr. W. H. Ellis, of Boston.

Mr. Edward S. Shaw (by letter).—Referring to the first point brought up by the author of the paper under discussion; the safe reduction of the live load, upon the foundations of a many-storied building, from the live load used in computing the strength of the floors of the building; the writer agrees with the author that a considerable reduction is allowable and desirable from the point of view of rational and consistent proportioning of the several parts of a building; but does not allow that a reduction of this live load to only 25 per cent. of the floor load is advisable, although considered "abundantly safe" by the author. There is often considerable uncertainty about the dead weight of a building; changes in

this item are sometimes made during construction, and the effect of wind pressure and eccentricity of loading is not always fully considered.

Assuming that the floors of a steel-frame office building have been designed to carry a live load of 100 pounds per square foot, with the usual unit stress, a live load of 60 pounds per square foot upon all floors is suggested as a suitable basis for figuring the foundations.

The writer finds, by reference to his notebooks, that he has figured pressures ranging from $2\frac{1}{2}$ to $3\frac{1}{2}$ tons per square foot, on the base of steel beam and concrete column footings, on gravel or stiff clay, and about the same on masonry footings on the same material, in foundations of Boston buildings, when he has designed the steel frame or has been consulted in regard to the foundations. Where eccentricity of load has been considered, the extreme pressure has risen to 3.85 tons per square foot, and, with wind pressure added to dead and live loads, to 5.2 tons per square foot.

The above pressures were chiefly, if not entirely, found by the use of a live load of not less than 100 pounds per square foot on all floors.

In regard to the proportioning of pile foundations, the writer does not agree with the common practice of endeavoring to estimate the strength of a pile to support its permanent load by its rate of penetration during the last blows of the hammer. This practice seems comparable to the attempt to determine the strength of the superstructure of a bridge by first building the bridge and then measuring its deflection under a moving load.

The word "friction," to express the resistance to sinking caused by the adhesive pressure of earth upon the periphery of a pile, seems objectionable, and, although it has the sanction of writers who are regarded as authorities, has long been discarded by the present writer, who prefers the name often used by practical pile drivers, "suction," especially in a clay or silt bottom. The word friction is objectionable because the resistance caused by the peripheral pressure or adhesion is not known to follow the well-known laws of friction given in the text-books on mechanics.

The writer divides the total resistance of a pile against sinking under its permanent load into two components, viz, tip resistance and peripheral resistance, and considers that it is safe to neglect the element of tip resistance in all cases of soft ground or where there is any uncertainty as to depth of a hard stratum to or into which the piles may be finally driven, and, for the amount of peripheral resistance, considers values ranging from 200 to 500 pounds

per square foot safe for ordinary cases—the amount to be used depending upon the nature and hardness of the bottom into which the piles are driven. This is determined by a method of sounding or boring which gives the degree of hardness expressed in figures from about 10 to 350 or 400 and in six general divisions, as follows:

No. 1—under 25.—Soft: Silt; loose sand; soft wet clay.

No. 2—25 to 50.—Medium: Compact sand; medium clay; fine gravel.

No. 3—50 to 100.—Hard: Very compact sand; gravel; stiff clay.

No. 4—100 to 200.—Very hard: Compact gravel; clay hard pan.

No. 5—over 200.—Exceedingly hard: Boulder clay; shale or soft rock.

No. 6.—Impenetrable; hard rock.

The writer considers that the total work done in driving a pile, as measured by the product of the number of blows by average drop of hammer, is as important in determining the safe load on a pile as its final resistance to driving. Also that it is important to observe the varying resistance of the pile to the hammer throughout the driving.

The author's statement that in his judgment it is unnecessary to specify the size of a pile at the butt, and that a spruce pile 6 inches in diameter at the tip is sufficient for all ordinary cases of foundations, is at variance with the theory, experience and practice of the writer, who would consider it safe to place a considerably greater load on a pile with 8-inch tip and 14-inch butt than on one with 6-inch tip and 10-inch butt. In the first instance the peripheral area of a pile 25 feet long is about 72 square feet, and in the second case only 52 square feet. In a bottom of 1 and 2 degrees of hardness, with piles driven a little into the third degree, a peripheral resistance of 300 pounds per square foot is usually safe, and this would give a safe load upon the larger pile of 10.7 tons, but on the smaller pile of only 7.8 tons, or only 73 per cent. of that on the larger pile.

It is admitted that spruce piles, as furnished for foundations in this city, do not usually run to 14 inches butt for a 25-foot pile, and this case is taken merely to illustrate an argument. A specification which the writer has used for spruce piles and considers practicable is that they shall have a diameter of 7 inches at tip and, for piles 35 to 40 feet long, half of the piles to have a diameter of 12 inches and half a diameter of 10 inches, measured at a point

3 feet from the butt when the pile is "made," or at the point where the piles are cut off after driving. All exclusive of bark.

In concluding, reference may be made to a difficulty which the writer has encountered in Boston foundations, viz, the variation, sometimes extreme and sudden, in the nature and hardness of the ground under the different portions of the same building. In one case mixed strata of clay and gravel, sloping at a considerable angle, 30 to 45 degrees (from memory), were encountered. In two buildings located on or near the old marginal or shore line the greater part of the foundations were placed upon the ground without piles, but pockets of softer material were found, necessitating the driving of piles over limited areas.

Mr. William Parker.—The most important foundation work done by the Boston and Albany Railroad in Boston recently is that for a seven-story, fireproof, brick warehouse at the East Boston Terminal. Borings on the site of the house showed that, at the north side, or the end farthest from the dock, hard bottom was 86 feet below the surface, which was at about grade 15 above city datum, which is 0.64 below mean low water. At the south end, or the end nearest the dock, hard bottom was about 105 feet below the surface. The different strata were filled material of miscellaneous character, or silt and shells, from the surface down from 12 to 20 feet, and the remainder all clay. This clay was classified as "soft clay" by the party employed to make the borings.

The building is 220 feet long and 140 feet wide, the latter dimension being that of the southerly end, which is 30 feet from and parallel with the head of Dock No. 1. At the head of the dock there is a retaining wall, resting on piles which are cut off at mean low water. The earth slopes away from the wall to the full depth of the dock at a line from 60 to 100 feet distant, the water being about 35 feet deep at low tide.

The foundations extend out beyond the building lines so that they cover a space 233 by 153 feet. Within this space were driven about six thousand spruce piles, generally 40 feet long, spaced about 2.5 feet between centers with their tops at grade 6. The earth was excavated 1 foot below cut-off of piles and the space around piles filled with Portland cement concrete, using the proportion of 1 cement, about 3½ sand and 9 broken stone. The entire area was then covered 2 feet 6 inches thick with Portland cement concrete, using the proportions of 1 cement, about 3 sand and 8 broken stone. Upon this foundation were constructed frustums of pyramids for the column footings and the footings for the walls, both of concrete, the same as that next above top of piles. The bases of the frustums

came together at the top of the 2 feet 6 inches thick mass of concrete and had their tops, which were about 5 feet square, at grade 16; hence they were 7 feet 6 inches high. Wall footings were prisms of concrete resting on the main foundation the same as the column footings. This construction of column and wall footings was possible as there was no desire to have a basement to the building.

There were about 10,000 cubic yards of concrete in the foundations.

Before plans were made a test pile was driven about 50 feet from the water end of the building. This pile was driven about 40 feet below grade 5, and afterward loaded with 30 tons of pig iron without any settlement. After the pile had been driven about 20 feet, the average fall of hammer and number of blows required for each 2 feet of length was recorded, as well as the penetration and fall at the last blow. After the pile had remained in place for two days it was struck five blows and the fall of the hammer and penetration noted for each blow. Calculations were made to show the sustaining power at the different stages of the driving, using the *Engineering News'* formula, and the frictional resistance per square foot of pile surface was also figured, using the calculated sustaining power as a basis. It was thought that these latter figures would be an aid to judgment while the whole matter of length of piles to be used was being considered.

The pile was actually about 51 feet long, so there was about 10 feet of it above the ground, which made it possible to apply the 30 tons test load in quite a satisfactory manner, about one-half being supported by a platform held up by heavy sticks bolted to the pile near the ground and the other half by a platform at the top of the pile. The pile was driven very straight, and there was little, if any, tendency for the load to tip.

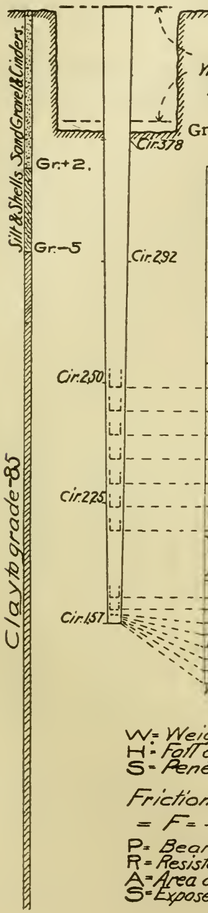
The accompanying table gives the record of the driving and the results of calculations.

It may be of interest to speak briefly of an experimental pile driven on the slope of Dock No. 1, at a point about 130 feet distant from where the pile just described was driven.

A water machine was used, with a hammer weighing 1980 pounds, having the rope attached, the depth of water at the point where the pile was driven being 3 feet and upwards, according to the height of tide. At first a pile 44 feet long was driven and then another 42 feet long placed over it, the abutting ends being carefully squared and joined with a short section of 12-inch wrought-iron pipe. After this compound pile had been driven so that it was about 30 feet into the clay, notes were taken and calculations made

as in the case of the pile driven on land. A few of the results are as follows: For distances of 40, 50, 60, 70 and 78 feet in ground the safe loads and frictional resistances are respectively 12,600 and 114, 14,256 and 99, 20,457 and 115, 23,004 and 102, 24,460 and 101. The penetration for the last blow, with a fall of twenty feet, was 2.4 inches.

BOSTON & ALBANY R.R.
N.Y.C.&H.R.R.R. Co. LESSEE.
SEVEN STORY WAREHOUSE
EAST BOSTON.
TEST PILE.



Average distance in ground	Number of blows.	Total penetration	Penetration per blow	Fall of hammer.	$\frac{2WH}{S+1}$ = Safe Load, $\frac{1}{6}$ Ultimate	Frictional resistance between Earth and Pile per Sq. Ft.
Feet.		Feet.	Inches.	Feet.	Pounds.	Pounds.
21	7	2	3.43	12	11106	236
23	10	2	2.40	10	12058	230
25	9	2	2.67	11	12322	213
27	10	2	2.40	11	13264	209
29	11	2	2.18	10	12893	186
31	15	2	1.60	10	15769	211
33	17	2	1.41	10	17012.	211
} Data incomplete						
38.5	6	1	200	20	27333	283
39.5	5	1	2.40	20	24117	240
40.	Last blow.		2.38	20	24260	237
1st Blow after rest.			1.44	20	33606	329
2nd "	"	"	1.56	20	32031.	312
3rd "	"	"	1.68	20	30597	297
4th "	"	"	1.80	20	29286	282
5th "	"	"	1.92	20	28082	270
With total test load of 60,000 lbs - No Settlement.						580

W = Weight of hammer = 2050 lbs.
H = Fall of hammer in feet (rope attached)
S = Penetration in inches.

Frictional Resistance per Sq. Ft. between Earth and Pile $= F = \frac{P - R.A.}{S+1}$.
P = Bearing power of Pile.
R = Resistance of Earth per Sq. Ft. = 2000 lbs (Assumed)
A = Area of Cross Section of Pile at lower end.
S = Exposed surface of Pile in Sq. Ft.

F. D. Bardwell Del.

After the pile had remained three days it was struck three blows with a 20-foot fall of hammer, which gave a penetration for the first blow 1.8 inches; for the second and third blows, each 1.32 inches, the safe load and frictional resistance for the three blows, using the above data, being respectively 28,285 and 116, 34,138 and 144, 34,138 and 145. The two sections of the pile were

of oak, with the bark on, and varied in size from 7 inches in diameter at the tip of the lower pile to about 14 inches at the butt of the upper pile.

Of the seven floors of the warehouse, three were calculated for a live load of 400 pounds per square foot, two 300 pounds and two 250 pounds. In estimating the load to come on the foundation 250 pounds per square foot for all floors was taken as the live load. Using this assumed live load, the total weight per pile is from 10 to 13 tons.

Just before excavating, or as excavation proceeded, sheet piling was driven to hold up the bank and to keep out water, so there was but little trouble with water.

Work was commenced on the end next the dock and quite an area was kept down to grade in advance of the pile driving. By this method it was thought that there would be the least danger to the sea wall near by, as the compression of the clay due to the pile driving would have a chance to force up the area in advance of the work on the land side as the driving advanced, instead of working in the direction of the sea wall. As it was, the wall moved bodily out toward the dock 9 inches at the center, the ends being buttressed against walls at right angles to it. The coping was moved into line at the time a platform was built in front of the wall, and no further movement has been observed. The earth around and in advance of the driving rose from 1½ to 2 feet.

As before stated, the piles driven were spruce, generally 40 feet long. Some of these went so easily that they will not, by calculation, give quite the factor of safety reckoned on. A few 45-foot piles were driven in a soft spot which was found near the end farthest from the water. A place on the east side was found where the driving was so hard that the contractor was allowed to use piles only 35 feet long.

The greatest number of piles driven in one day by the four pile drivers used was 174, the greatest day's work for any one driver was 60 piles, and the average day's work for one driver was 38 piles.

Benches have been established to watch any settlement that occurs.

The building was put in use in March of last year. After this first eleven months of use, levels show a slight and fairly uniform settlement, nowhere exceeding 1 inch, although there are no signs about the structure to indicate any movement due to settlement of foundations.

There is an old four-story brick and stone warehouse 50 feet

from and parallel with the new warehouse which has a pile foundation of the usual construction of isolated piers and probably a double row of piles under the walls. It has been in use, and generally heavily loaded, for about fifty years, with no signs about the structure to indicate settlement.

The grain elevator, of 1,000,000 bushels capacity, between Docks 3 and 4, built partly in 1869 and partly in 1874, has a pile foundation in material similar to that found at the new warehouse, and there is no evidence of settlement. Two borings made at this elevator about 1896, by the State Board on Docks and Terminal Facilities, found hard bottom at 63 feet and 79 feet below mean low water.

In some of the papers and discussions the question of grade for cut-off and the action of worms on piles has been taken up. In this connection the following may be of interest: When constructing a freight house in 1898 on the site of the Old Colony Railroad train house, piles supporting the old wall footings were found at grade 9.5. Generally these piles were in good condition, only a small amount of decay being found around the top edge; but in one spot they were badly rotted from 6 to 10 inches down from the top. They were cut off at grade 7 and used for the support of the new wall. At this time the nearest body of water was Fort Point Channel, about 600 feet away.

All of the piles for the new structure were cut off at grade 7.

When constructing the foundations for a coal pocket on Lehigh Street (since discontinued) piles were found perfectly sound at grade 11, after being in place probably forty-five years. Piles for the support of the new building were cut off at grade 7, and for the ash pits at grade 8. Fort Point Channel was at that time about 300 feet away.

When removing the old piles of Wharf No. 3, East Boston, many of them, perhaps nearly all of the original piles, were found eaten by the limnoria. A section cut from a representative pile shows a loss of about 30 per cent. These piles had probably been in place at least fifty years.

In piles recently removed from one of the corners of Pier No. 4, which had been in place about ten years, both the limnoria and teredo were found. The former was found in nearly all the piles, but had not done much damage, not more than 2 or 3 per cent. of any one cross section being destroyed. Although the teredos were found in a large proportion of the piles removed, they were few in number and had done little damage.

MR. LEONARD C. WASON.—The writer will endeavor to confine his remarks to such types of foundations as have not already been described by others, and these will be mostly concrete foundations.

Doubt has been expressed as to the use of concrete and steel I-beam grillage for foundations of Boston buildings. The writer has constructed a number of foundations of concrete re-enforced with square twisted steel in the following manner:

For piers the footings were octagonal in plan view, the area being determined by the bearing power of the soil. The thickness of the slab was approximately one-half the amount of projection of the footing from the edge of the base plate which supported the column. Steel was placed near the bottom of the footing, the bars being arranged at right angles to each other, and also to form diagonals, thus distributing the load of the column uniformly over the area of the footing. Under the Ferdinand Blue Store are some footings having a diameter of 10 feet 8 inches and a thickness of 28 inches, which carry loads of 280 tons.

The advantages of this type of foundation are (1) a considerable amount of the digging necessary in order to get the required spread in a stone or plain concrete footing is saved, and (2) shoring and often pumping are avoided by the permissible shallowness of the excavation. The large saving in material and labor makes a saving in cost and time of construction.

In quite soft soils care should be taken to avoid placing the footing too near the surface. In one case which has come to the writer's notice the soil has been squeezed upward, while the footing has settled, being on a soft clayey soil which was slightly overloaded.

This same type of footing is also applied to walls. Under one extremely heavy wall of a manufacturing company's building, on quite a soft soil, a spread of 30 feet was obtained in a depth of 52 inches, the thickness at the edge of the footing being only six inches. The cross section resembled a very flat truncated cone. The concrete thoroughly protects the steel from corrosion, so that there is no danger of any deterioration or ultimate failure of this type of foundation.

In several buildings the foundation walls have been made of concrete, and, because of the great crushing strength of the material, the central portion of the concrete has been cored out, making the walls hollow. This makes them much drier than solid walls, the bottom of the cores in the wall being drained on the outside of the building. The Chelsea Police Station is built on a very wet soil and has walls of this type. Although the plastering was placed

directly against the outside walls in most cases, it has never wet through nor sweat.

Another modification of the foundation walls, which has been used to some extent, especially in exceedingly deep cellars where a large amount of earth must be retained, consists in using a thin wall, reinforced by vertical steel bars, which make it stiff, like a floor slab on edge, the wall having sufficient cross section to carry any dead weight which may be placed upon it, and being spread by the cellar pavement at the bottom. The sub-basement, basement and first floors act also as spreaders. Thus a large area of valuable space is saved, as well as a considerable portion of the cost of massive retaining walls.

Concrete piles have not been used in this locality, so far as the writer knows; but, should the demand arise, there are several types which may be successfully used. One method is to cast the piles of concrete, reinforced with steel, and, after they are thoroughly set, to drive them with a pile driver in the ordinary manner, except that a special cap is necessary to prevent shattering the heads of the piles.

A second type, which has been used extensively in the West, where the soil is of a clayey or loamy nature, driving, therefore, being easy as compared with that through the strata of varying material, hard and soft, which we have in this locality, is the Raymond pile. This consists of a thin shell of sheet metal, inside of which is placed a strong core, which takes the shock of the pile driver. After the pile has been driven to the proper depth, the core is collapsed and withdrawn. The shell is then filled with concrete, either plain or reinforced.

These piles are always made with a large taper, usually being 6 inches in diameter at the point and 20 inches at the top. Thus a large bearing area is obtained, and, by tests made in Chicago, one concrete pile carried as much as three common spruce piles driven to the same depth and having the same diameter at the points.

A third type, proposed by Mr. E. T. Barker, of Boston, is to drive two pipes, one inside the other, the outer one having a steel shoe. This is driven 2 or 3 feet into the hard bearing soil. The inner tube is then removed, and it brings with it the enclosed earth. This tube can be opened, and it then discloses to view the nature of the earth through which the tube has been driven.

If a larger bearing is desired, a shaft, having scoops attached to the bottom, is lowered through the tube, and, by being revolved, digs the bottom to a greater diameter than the tube. The earth is then removed and concrete is filled in, the outer tube being with-

drawn slowly as the concrete is placed. In this case the concrete is filled rigidly against earth which has not been shaken or disturbed by driving.

One of the advantages of concrete piles is the fact that they can be finished just below the cellar floor, which saves the large amount of labor and expense necessary to cut wooden piles at grade 5, to cap them with masonry, and bring them up to the level at which the concrete piles were finished. Another advantage is that, in docks and marine work, they are proof against the attacks of the teredo navalis. On making allowance for difference in bearing power of one concrete pile and the three equivalent wooden piles, the concrete is the cheaper.

In one case which came to the writer's attention concrete was placed in the ground over a foul spring, which emitted sulphuretted hydrogen gas, and the concrete failed to set. It was later dug out and the sources of the spring were drained, so that no more gas escaped, and when the concrete was again placed it set hard and entirely satisfactorily to the engineers. It has been the writer's observation that green concrete must be carefully protected against conditions which are absolutely powerless to injure the concrete after it is set and thoroughly hardened.

Mr. J. R. Worcester (by letter).—The full discussion of the subject has been very gratifying to the writer of the paper, and has brought out a number of the peculiarities of foundation work occasionally encountered. The fact that in general the experience of those contributing to the discussion has borne out the figures mentioned in the paper is particularly pleasing.

It is very satisfactory, after having labored with a law which one considers objectionable in some respects, to come face to face with the men, who, if they did not make it, at least took part in framing it, and who calmly assure us that, if it is not right, it is our business to say so and endeavor to have the defects remedied. It is still more unusual, and, at the same time, equally satisfactory, to come face to face with the originator of an "unwritten law."

As the result of the latter information with regard to range of danger from worms, the writer is disposed to withdraw his suggestion for cutting the piles at grade 4, when exposed to the action of tide water, and to replace this with the advice that foundation piles, not accessible for renewal, shall be invariably protected from the action of tide water by sheet piling and filling, if necessary.

The crib foundation mentioned by Mr. Snow and others was not referred to in the paper, for the reason that the subject was carefully limited to foundations in the city proper, where, proba-

bly, crib foundations have not been required, though it is true that they have been used in the immediate vicinity.

In view of the evidence with regard to concrete that does not set and the uncertainty, sometimes, with regard to the cause for its not setting, it seems as if there should be some provision in our specifications for the removal of any concrete which, either from accidental or other reasons, fails to set in a certain time. With this provision, if enforced, it seems as if there need not be any fear of laying masonry on the concrete capping for piles.

The formula for the capacity of piles suggested by Mr. Davis is certainly very satisfactory, provided you are sure enough of your assumed units, but it is exactly upon this point that we lack definite knowledge, and where we make so many assumptions, it seems as if we might about as well assume the capacity of a pile as a whole in certain kinds of material without making any computations at all.

Mr. Shaw has evidently misunderstood the writer's recommendation to specify only the tip diameter of a pile. There is no doubt that the size of the pile has much effect upon its sustaining power, but the point which the writer intended to make was that with piles such as we obtain in this market there is nearly the same taper, and we run little risk of the butt diameter being too small if the tip is not less than 6 inches. In selecting piles it is easy to measure the tip, but the diameter at the butt cannot be known until we know how far they will be driven, and if, for any reason, a pile meets with too great resistance to be driven its full length, the greater resistance would generally insure its efficacy, even if where cut its diameter underruns a specified figure.

FOUNDATIONS.

By George B. Francis, Member Boston Society of Civil Engineers.

[Read before the Society, February 18, 1903.*]

In modern construction, both for high buildings, in which the loads on the foundations are very large compared with buildings of twenty-five years since, and in power-plant structures, chimney and other heavily loaded construction, the necessity of obtaining all the information possible is imperative.

BORINGS.

In some cases simple test pits will prove sufficient; in others it is advisable to make borings, which will bring to light the character and amount of the different strata encountered, preferably by means that will show core samples rather than the common wash borings.

Rod soundings are quite uncertain for any great depth, and are quite delusive in clay foundation on account of the friction on the rod, which is sometimes sufficient to give entirely wrong impressions as to the hardness of the strata.

In important cases it is well to supplement the borings with test piles to determine the real resisting power of the strata by actual observations rather than by reasoning from the borings.

There is never any danger of knowing too much about the strata which are out of sight.

PILES.

Very frequently, after all the data possible have been obtained, the engineer is still in doubt as to the necessity for using piles and increasing the consequent expense, and is uncertain as to the advice he ought to give.

In such cases an investigation as to the cost of the structure with and without piles will usually develop the fact that the cost of piles (particularly in building construction) will add a very small percentage to the total cost of the structure, usually very much less than 5 per cent., frequently as low as 2 per cent.

After ascertaining this fact, it should not take long for an engineer to make up his mind what to do in doubtful cases, viz, take the safe course, reasoning that it would be altogether wrong to jeopardize the 95 per cent. for the sake of the 5 per cent.

GRILLAGE.

Sometimes an engineer is puzzled as to whether he should or should not use a timber grillage on the heads of the piles, rather than a concrete grillage around and over the heads of the piles.

*Manuscript received May 11, 1903.—Secretary, Ass'n of Eng. Socs.

If the material around the heads of the piles is fairly hard, say hard enough to hold up the workmen without their sinking into it more than an inch or two, it is usually safe to use concrete, but if it is quite soft, so that the concrete while fresh will sink into it or mingle with it, timber grillage should be used, provided it will be permanently wet.

In using timber grillage none of the load thereon should be considered as transmitted to the earth. The rigidity of the piles will prevent this.

At times the best form of grillage is a solid timber platform made up in three courses of any suitable thickness, this being preferable to simply capping and flooring when piles are so irregularly driven that they do not line up well for the caps. The solid floor will cover and bear on every pile head for its full area.

RIPRAP.

Where piling is used to support masonry abutments or retaining walls, through soft strata, it is equally important to look after the lateral force as well as the vertical force. If the piles move forward horizontally the abutment or retaining wall will be injured, if not thrown down. To counteract such movement provision should always be made for riprap, in large quantities, against the face of the piling and walls, or there should be batter piles. The latter cannot be driven at a good bracing angle, and it is better to rely on a good quantity of riprap.

In some cases it is necessary to support buildings containing machinery and subject to vibrating influences on piles through very soft strata. The common way to reduce or stop vibration of the foundation in the soft strata is to surround the site with heavy sheet piling close up to and against the foundation, to present a very large surface against the soft strata. Even this is not sufficient in all cases of deep mud, and it is further necessary to deposit a large quantity of riprap outside of such sheeting to increase the mass and get a bracing effect for the foundation.

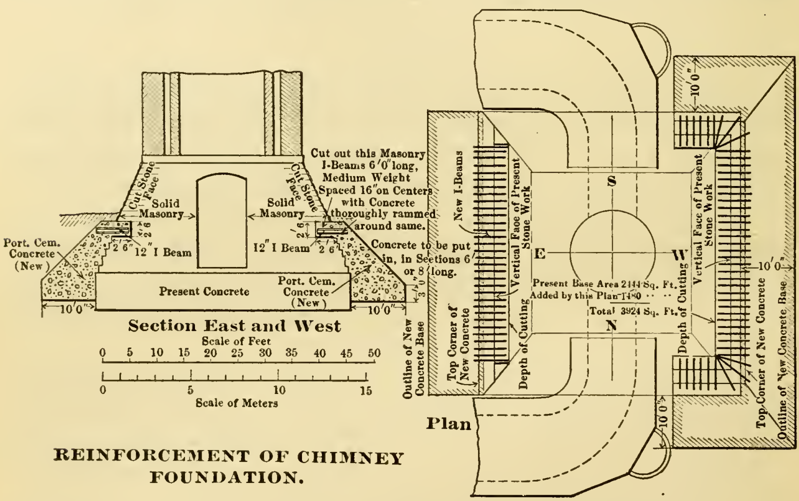
FOOTINGS.

When it may be concluded that piles are not required, even though the natural earth is not of the best character for foundations, it is good practice to spread the footings to cover the greatest area of natural earth practicable. Such a method has long been the practice in Chicago. Failure to do this has caused a great amount of trouble and expense.

A recent example of this character, where the writer was called in to advise, is a 250-foot chimney, having an interior diameter of

20 feet and a base area about 50 feet square. It was founded upon clay about 16 feet below the surface of the ground. Within two years of its erection it had settled on an average 1 foot, with no prospect of stopping. Furthermore, one side had settled about 6 inches more than the other.

The advice was to cut into the base of the stack at a point just below the surface of the ground, about $2\frac{1}{2}$ feet deep and $2\frac{1}{2}$ feet high, on the two available sides, the high and the low, to insert steel beams and concrete into the slots and then to enlarge the base area, trusting to the beams and concrete to divert some of the load onto the new foundations. This method was carried out, with some variation, on the low side, and it is now reported that the settlement is checked. Should the high side settle, so as to bring



REINFORCEMENT OF CHIMNEY FOUNDATION.

the chimney back plumb, the same treatment will then be applied to the high side. If not, it will remain as at present, with a lean of upwards of 3 feet, unless the company choose to undermine the high side to bring about a plumb condition, an experiment not advisable.

The accompanying figure exhibits the method described above.

CONCRETE.

Engineers, particularly outside of New England, are using Portland cement concrete to a very large extent, one might almost say exclusively, for bridge piers, abutments and retaining walls. It is proving to be a very suitable material for such structures, and in many cases it can be produced from local materials, where stone is out of the question. In other instances it avoids the

necessity of derricks. The cost is also more favorable than with stone masonry.

A couple of years ago, as an experiment, the writer built some 16-inch foundation walls about 8 feet high out of unscreened bank gravel and Portland cement, using 1 part cement and about 12 parts gravel. The result was good, and the walls are still standing in good form and doing good service.

A great improvement has been made in the quality of Portland cement during the twenty-five years just passed, and to-day it is one of the best and most durable articles for many kinds of construction.

In the construction of concrete masonry it is preferable to obtain a good exterior surface by means of wooden forms, with the surface of the wood planed, against which the concrete masonry is deposited, rather than to plaster the surface after the forms are removed. The plastering is liable to scale off if not put on under ideal conditions.

It will also improve the surface appearance of the concrete if it is washed down one or more times with a thin grout or wash of Portland cement. To hold the form in place without exterior bracing it is customary to use wire strands at frequent intervals, allowing the wire to run through the walls and afterwards cutting the wire off flush with the face of the concrete.

The use of expanded metal for bonding purposes is also frequently desirable.

The placing of anchor bolts in engine foundations is necessary, and sometimes, to the inexperienced, it is puzzling to know just how to arrange for their adjustment or removal.

As to adjustment sideways to fit holes in the bed frames, it can be done in a simple and inexpensive way by placing vertical tubes of ordinary corrugated galvanized iron conductor pipes in the concrete, instead of more expensive wrought-iron pipe or clumsy wooden boxes. Where possible, it is well to arrange the concrete around the bottom of the anchor rods so that the nut can be gotten at with the hand, but, if the anchor rods are numerous, this cannot always be done. In such cases a cast-iron box to hold the nut is imbedded in the concrete, and then the rod can be removed at any time.

*From time to time engineers are obliged to pass judgment on

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*These few notes are made, not for the benefit of the expert, but rather for those of less experience, and it is hoped they will make clear some of the puzzles which all engineers have to solve at one time or another.

the allowable pressure on the natural stratum which is to support engineering structures, as it goes without saying that in the final analysis the "earth must support all structures."

No rule can be laid down which will be safe to apply in specific instances. Surrounding each case there are usually some conditions which modify conclusions based only on the character of material immediately under the structure in hand. As instances, the following conditions may be recited:

Side hill work.

Spring and ground water.

Running water to scour.

Excessive freshets.

Dredging operations near by.

Hurricanes.

Doubtful underlying strata.

Crowding embankments or fills.

Mountain slides.

Loading of adjacent areas.

It is also very difficult to divide the various kinds of earth and rock into sufficient classes or into classes that all engineers will interpret as the same or nearly the same, as there are many local characteristics, as well as names, which it will not be safe for the novice to interpret.

In reply to the very general question as to "the safe supporting loads of different classes of earth," I once used the following: "Make the base area as large as you can, within reason, when there is nothing to interfere, and when you cannot get an area as large as you would like, use all you can get; this rule not to be followed in extreme cases." Even with this, experience must teach what are and what are not extreme cases—extreme in the sense of very soft strata, which are not fit to place anything upon, or extreme in the sense of ridiculously small area, though of fair supporting power.

There are several classes of strata that are readily definable, such as ledge rock, hard pan, gravel, clean sand, dry clay, wet clay and loam, and when these strata are of considerable thickness and uniform for considerable areas, they may be loaded with safety (provided the material placed thereon is not of less density than the natural material upon which it is placed, viz, concrete or brick work on ledge rock) as follows:

Ledge rock, 36 tons per square foot.

Hard pan, 8 tons per square foot.

Gravel, 5 tons per square foot.

Clean sand, 4 tons per square foot.

Dry clay, 3 tons per square foot.

Wet clay, 2 tons per square foot.

Loam, 1 ton per square foot.

As there are so many kinds of hard pan, gravel, sand and clay, with varying mixtures of these materials, no specific rule can be laid down without making it for minimum loadings, and these with certain grades of materials will be ridiculously small; then, again, it is often right and proper to risk greater loadings for temporary or unimportant work.

After all is said on this subject of "safe allowable pressure," conclusion reached by varied and ample experience is the only safe and proper guide.

DISCUSSION.

Mr. R. A. Hale.—In connection with Mr. Francis's paper it would be interesting to know the pressure, in tons per square foot, of the chimney which he mentions in comparison with the chimney designed and built in Lawrence in 1873 by Hiram F. Mills, C.E. This chimney is 225 feet in height. The foundation on which it is placed was clean, sharp mortar sand 19 feet below the surface of the ground. It was inclosed by sheet piling, making an area 35 feet square, the sheet piling being driven about 5 feet into the ground. A bed of concrete 1 foot in depth was spread over this area and coarse granite ledge stone was laid for about 7 feet in height. Then the chimney flue was constructed and the brick work of the chimney was constructed above that. The total weight of the chimney was about 2150 tons; the area of the base was 1225 square feet, making a pressure of about 1.8 tons per square foot, and the wind pressure was estimated in the vicinity of one-third more, making a total of 2.4 tons per square foot. There has been no settlement in the foundation of the chimney, nor any disturbance, so far as is known. At one time the chimney was struck by lightning and one side considerably shattered, but it has been repaired and a lightning rod has been placed on it, so there has since been no trouble from lightning.

Two other chimneys in Lawrence, one 225 feet and another 250 feet high, have been built in somewhat similar manner, with pressures within the limit stated, and the material is in general about the same as in the first instance. There is one chimney that is built where there is the bed of an old brook, and, owing to mud and soft material in that location, it was necessary to drive piles. I have no figures in regard to this case, but I think the weight per square foot was less than in the former cases, and there has been no perceptible settlement.

In regard to materials for general mill foundations, we must remember that the foundations vary greatly in individual cases, but we find the sharp mortar sand already spoken of, and also a yellow loam. The weights are usually limited to about 2 tons per square foot, and I know of no serious trouble as having been experienced. In some cases, where the foundations were not sufficiently compact, it was necessary to drive sheet piling in order to avoid the possibility of water percolating out, and then to put in a bed of concrete, from which the foundation started. On the South Canal, where many mills have been erected, we find various strata of coarse river sand, through which the water percolates freely, and this occasions difficult excavating. In such cases it was necessary to drive sheet piling in order to get the timber bottoms of the wheel pits in and to have the masonry started on the timber bottom and plank flooring necessary for the wheel pits.

THE FAILURE OF A SEA WALL AND ITS RECONSTRUCTION.

By Clarence T. Fernald, Member Boston Society of Civil Engineers.

[Read before the Society, February 18, 1903.*]

The yard at the East Cambridge power station of the Boston Elevated Railway Company, formerly the property of the Cambridge Glass Works, has a frontage of about 471 feet on Millers River and an area of 217,807 square feet, as shown in Fig. 1. The yard is used for the storage of various kinds of track material, such as rails, ties, paving blocks, etc., besides the coal used in the power station.

During the fall of 1901 about 12,000 tons of coal were piled upon the wharf directly in front of the boiler house, while at the same time there was a large pile of paving blocks extending for 50 feet along the westerly face of the sea wall, running back 50 feet onto the wharf, and from 10 to 12 feet high.

Under this load the sea wall and wharf directly under the coal run or in front of the boiler house began to yield, and before the load was removed had been pushed outward into the river about 12 feet and downward about 6 feet at the worst place. The wharf or pier extending along the face of the wall prevented its total collapse.

The old wall was probably built by the Cambridge Glass Works some time in the early sixties, as an extension of the wall along the Boston and Maine Railroad property, built soon after the passage of Chapter 278 of the Acts of 1847, establishing the harbor line on Millers River, no authentic record beyond this being obtained.

The wall itself, acting as a retaining wall for the solid filling, was no doubt adequate, but its foundation, which was uncovered when the wall was removed, showed conclusively the reason of failure under the heavy additional loading. The wall was built upon four rows of spruce piles, averaging 15 feet long by 7 inches in diameter, driven 2.5 x 3 feet on centers, penetrating about 13 feet of mud and 2 feet of clay, the tops being cut off at approximately grade + 0.50.† No capping was done nor any platform built, the granite footings being placed directly upon the pile heads; yet,

*Manuscript received May 26, 1903.—Secretary, Ass'n of Eng. Socs.

†Grades are referred to Boston City Base, which is 0.64 feet below mean low tide.

when the tops of the piles were exposed, it was evident that the wall bonded them sufficiently to make them hold their relative positions, *i.e.*, all moving together.

Upon this foundation the wall was built, 8 feet on the base, 13 feet high and 2 feet wide at the top, the granite blocks being largely wedge-shaped, few pieces except the cap stones being regular. Over the wall and partially supported by it was a wharf resting upon oak piles in front of the wall and upon spruce piles and solid filling directly back of the wall, and when the foundation

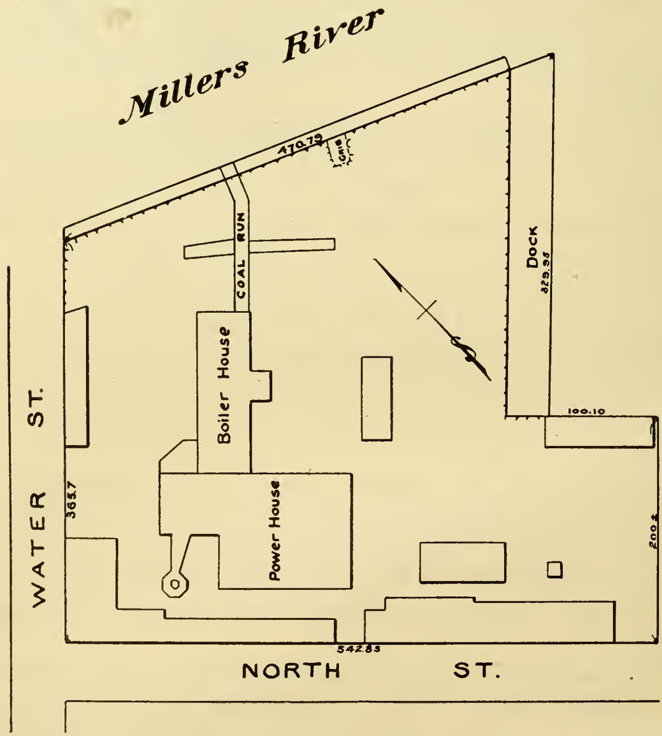


Fig. 1.

yielded the oak piles offered resistance enough to check the wall and filling from sloughing off entirely and pushing out into the river.

The appearance of the wharf before repairs were begun is shown by Figs. 2 and 3, and the manner in which the wharf and wall yielded by Figs. 4 and 5. As will be noticed in Fig. 4, the piles for the wharf were tied together longitudinally by girder caps, there being only the floor beams, drift-bolted to these girders,

FIG. 2. VIEW OF OLD WHARF, LOOKING WEST, SHOWING TOTAL OUTWARD MOVEMENT (APRIL 18, 1902).

Fig. 3. View of Old Wharf, Looking East, Showing Total Drop at Coal Run (April 18, 1902).

to resist the outward thrust. Each row of piles was consequently pushed over like a card house, offering but little resistance.

Fig. 6 shows clearly the tops of the piles supporting the old wall, and indicates, by their angle of inclination, the approximate distance through which they moved.

The conclusion naturally to be drawn from the foregoing facts is this: The excessive loading on the wharf compressed the soft mud directly under the filling. This displaced the mud in front of it, which, moving along the lines of least resistance, pushed out into the water, carrying piles, wharf and wall along with it, as shown in Fig. 7. The piles under the wharf were not long enough to penetrate into the clay and so offer the resistance necessary, while the short piles in the wharf offered only their individual resistances. That this was true was shown by the piles pulled out from under the wall, as none were over 16 feet long nor more than 9 inches in diameter at the butt. The tip for a short distance showed that it had been driven into clay, while the pile itself was bent or broken in the direction of the thrust, although the wood was perfectly white and sound.

In reconstructing the wall and wharf all the filling was excavated to approximately grade 2 back of the wall for a distance of about 16 feet and the old spruce wharf piles cut off. All the oak piles in front of the wall were pulled out, the better ones being saved for future use. The piles under the old wall were left in, however, as the difficulty of pulling them was great, and the inconvenience caused by them did not warrant the expense, the new piles driven, interfering but little with them.

The new wall built was 10 feet wide at the bottom, 3 feet wide on top and 12 feet 6 inches high, with a batter of $1\frac{1}{2}$ inches to the foot, ballasted on the back with quarry ships and the smaller stones from the old wall. For the foundation of this wall six rows of spruce piles, about 12 inches at the butt, averaging 28 feet long after cutting to grade + 0.50, were driven, the two rows next the face of the wall having a batter of 1 inch and 2 inches to the foot, respectively, while a spruce pile driven as nearly as possible to a batter of 6 inches to the foot was placed about under the center of gravity of the wall and between the other rows of piles. The tops of these piles were capped with 6 x 12-inch hard pine, drift-bolted to piles with 1-inch bolts, and on these caps a flooring of 3 x 6-inch spruce planking was spiked.

The first course of the new wall was laid entirely of headers averaging 10 feet by 2 feet by 1 foot 8 inches, the balance of the wall being constructed of the largest stones from the old wall and

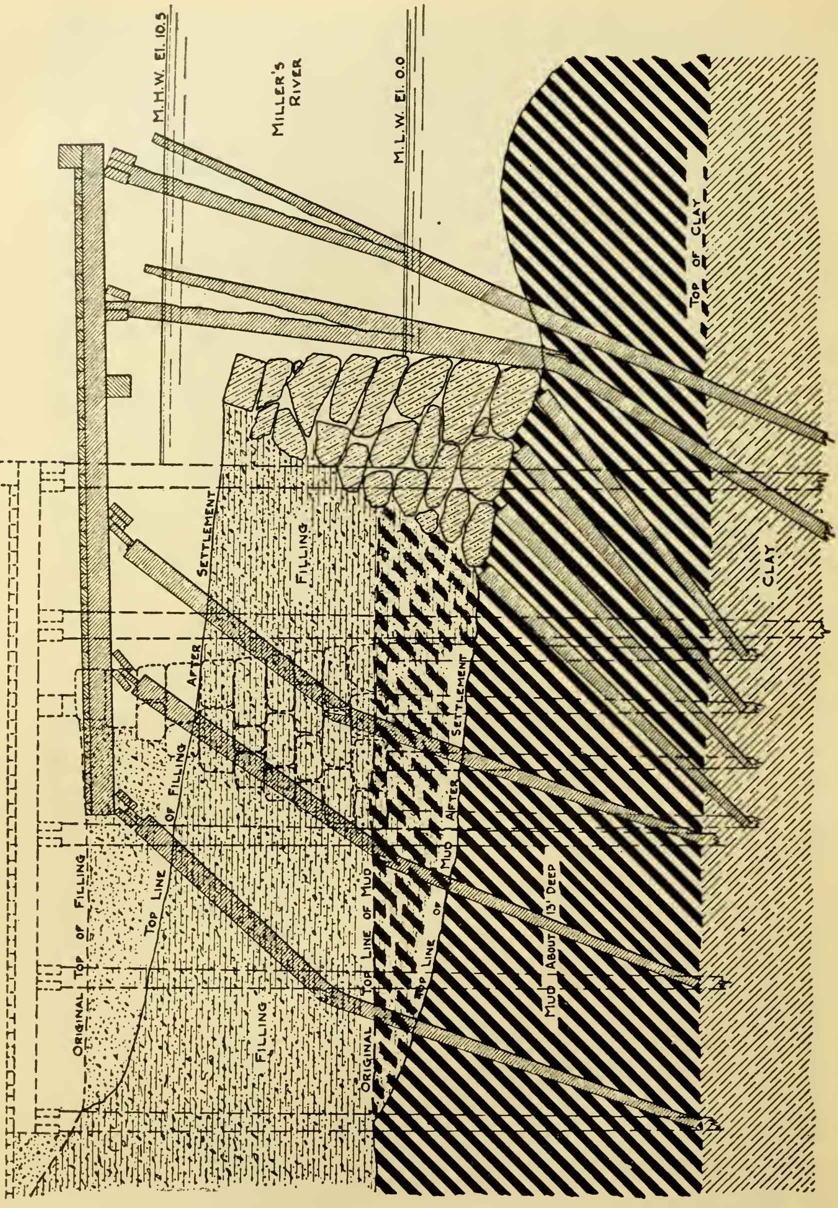


Fig. 7. Sketch of Wall after Failure. Taken at Point of Greatest Movement. Dotted Lines Show Original Position of Wall and Wharf.

new stone of regular shape (see Fig. 8, which also shows the three lines of spruce wharf piles tied and braced diagonally).

Outside of the new wall three rows of oak piles were driven, those of the two outside rows being 40 feet long, while those in the row next the wall were 34 feet long, this last row having the

Fig. 4. Old Wharf, Showing Planking and Stringers Removed (May 5, 1902).

Fig. 5. Removing Old Sea Wall (May 15, 1902).

Fig. 6. Foundation of Old Sea Wall, Showing Inclination of Piles (June 9, 1902).

Fig. 8. New Sea Wall, Showing Plank Foundation and Bottom Headers (August 9, 1902).

same batter as the wall. Tying each two rows of piles together, from the outside row of oak piles in front of the wall to the last pile driven back of the wall, were two girder caps 6 inches by 12 inches by 34 feet. On these were drift-bolted 4 x 12-inch floor beams, on which the 3 x 6-inch floor plank was spiked. The face of the wharf was built with a 12 x 12-inch stringer and rider cap,

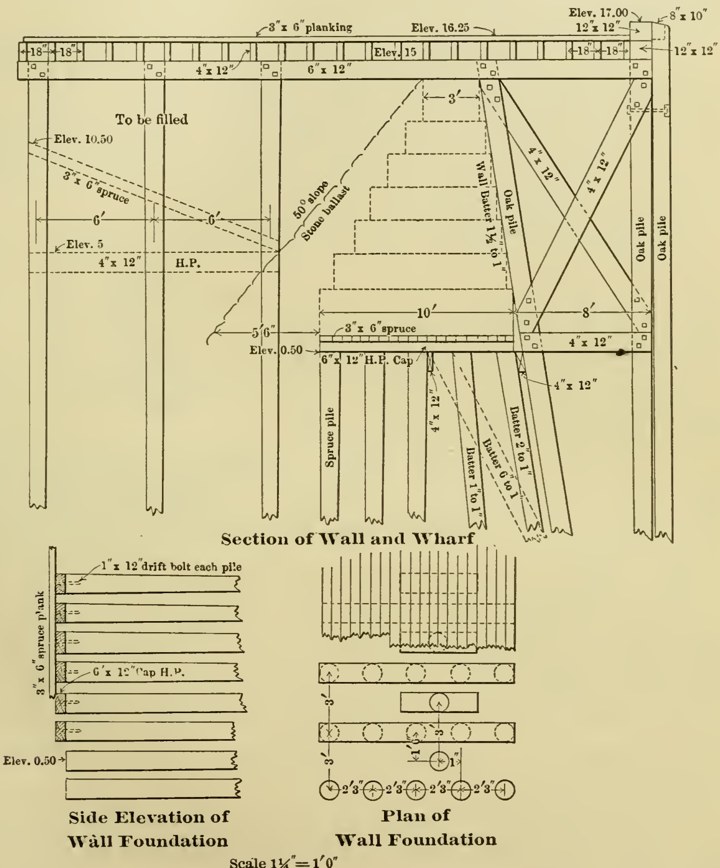


FIG. 9.

and had a fender cap 8 x 10 inches bolted between the fender piles. The oak piles were tied together by cross braces of 4 x 12-inch and two 4 x 12-inch low-water girders, all the timber used in wharf construction being hard pine. Fig. 9 shows a cross section of the new construction.

DISCUSSION.

Mr. Fernald.—As will be seen, these new spruce piles supporting the wharf averaged 39 feet long, extending through the mud 13 feet and then into the clay. The piles under the wall average 28 feet long, none being less than 25 feet, and were driven almost entirely into clay. The oak piles next the wall averaged 34 feet long, and the two outside rows of oak piles averaged 40 feet long.

The method of bracing the spruce piles back of the wall was deemed amply safe, as the piles were tied together above the mud line, braced diagonally against the probable thrust and then tied together again at the top by the girder caps, while the penetration of the piles into the clay would offer resistance enough to prevent any future movement without shearing the piles.

The outside oak piles were tied together by low-water girders and cross-braced as shown, and were tied to the piles back of the wall by the girder caps. The area back of the wall was refilled with the best of the material excavated back of the old wall, being composed mostly of cinders and refuse from the old glass works.

The new piles under the wall were cut off at grade + 0.5; the top of the platform was grade + 1.25.

The stone for the first course of headers averaged 10 feet long, were furnished by H. E. Fletcher, of Chelmsford, Mass., and cost about $2.50 per ton f.o.b. cars Boston, which in this case was at site of work.

Mr. Henry Manley.—The old wharf inclosed by a sea wall on piles, as shown by Mr. Fernald, is a typical form of old-fashioned wharf construction in Boston. It was admirably designed to meet the purposes for which it was built and was the outgrowth of many years of practical experience. It was very cheap, and, if not overloaded or weakened by dredging, it was a reasonably substantial structure.

The use of larger vessels, carrying larger freights, drawing more water, and which could not safely be allowed to ground at low water, proved the ruin of this class of wharf. Weakened in front by dredging, and overloaded in the rear by larger cargoes, many wharves have failed precisely as did the one shown to-night. The fact that the stones forming the old wall held together while the wall was overturned shows great skill in the bonding of the rough and shapeless stones used. These walls were generally laid directly from the sloops which brought the stones from the quarries, by the sloops' crews, and the stone layers acquired great skill in making good work from cheap materials.

Mr. Fernald.—No trouble is anticipated from any wash of tides or scouring effects of currents, as the back filling between the new piles was of coarse material placed on top of the mud as depressed. In addition, there was a considerable portion of the old wall, *i.e.*, some of the smaller stones, which were not removed and allowed to remain, acting as riprap.

The tidal currents in the river at this point are very sluggish, and I do not think any damage would be occasioned by them if no precaution whatever were taken to prevent wash.

Mr. F. W. Hodgdon.—I want to emphasize what Mr. Manley says about these old walls and the manner in which they fail. Generally what appears to be the failure of the wall is not due to the construction of the wall itself, but to the foundation. From my observation I think this will be found to be true in nearly every case. The wall itself keeps its form and position so long as the foundation is secure.

There is one wall in particular with which I am familiar, which failed two or three years ago at Commercial Wharf, in Boston. The wall was built in a similar manner to the one described by Mr. Fernald. Some twenty or thirty years ago it was examined by experts employed by the owners of the wharves, who reported that it would be safe provided the dock in front of it was not excavated to a greater depth than 12 feet at mean low water. A short time before it failed the dock in front of it was leased to the State to be used as a berth for the frigate *Minnesota*, then used as a training ship for the naval militia. This vessel drew about 23 feet, and in order to accommodate her the berth was dredged to that depth below mean low water. A short time after the vessel was docked the wall gave way, tumbling over into the dock, pushing the vessel across to the wharf on the opposite side.

In my own experience I have had walls built similar to those shown by Mr. Fernald, with foundations similar to the ones shown in his reconstructed wall, the foundations being about 9 or 10 feet wide and the wall about 4 feet wide on top and about 14 feet high. The land in rear of this wall was filled with soft clay, dredged in the harbor. The filling immediately back of the wall was first dumped in front of it and then raised by a dredge and deposited over the wall in rear. There was no trouble until one night the operator of the dredge got drunk and excavated the material down below the top of the foundation, placing it in rear of the wall. The result was that the whole wall was pushed out from 1 to 2 feet, the wall itself standing vertical, but the foundations moving forward in the same manner, apparently, as the wall described by Mr. Fernald.

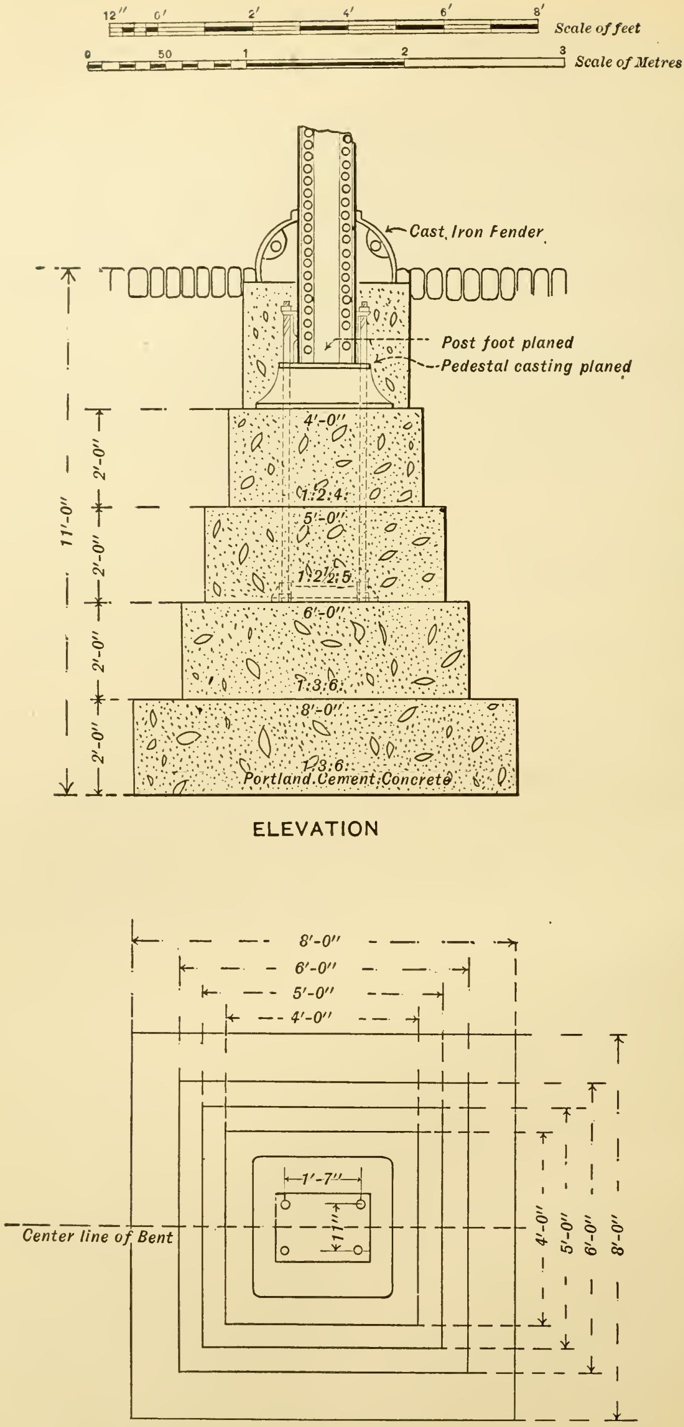
I have seen other walls which have failed in the same way, *i.e.*, the foundation giving out rather than the wall itself. As the result of my experience it seems to me that it is almost impossible to build the foundation of a wall in mud which will retain the filling in rear of it without moving. In one other case all the mud was excavated from the foundation, and after the piles were driven for the foundations of the wall the trench was refilled with coarse beach gravel faced on the dock side with quarry chips on a slope of about 1½ to 1. After the filling was placed in rear of the wall at one place where the filling was put in very rapidly the pressure forced the foundation piles through the gravel, and for this reason I have found it necessary to refill around the pile foundations with stone chips.

Question.—How long ago was the wall built?

Mr. Fernald.—It was built some time in the early sixties; the present Harbor and Land Commissioners' records begin some time in '66, and it was built before that.

Question.—Was that portion of the wall, which did not fail, rebuilt?

Mr. Fernald.—There was a section of about 57 feet where the wharf was reinforced; the wall at this point was not rebuilt, but it was reinforced by two rows of new piles being driven back of the wall and the old piles. These two rows of new piles were cross-braced together with the old piles and connected through to the oak piles outside of the wall by 6 x 12 girder caps. We feel that that part is as safe as the other.



FOUNDATION FOR THE ELEVATED STRUCTURE OF THE BOSTON ELEVATED RAILWAY. TYPICAL DESIGN.

FOUNDATIONS FOR THE ELEVATED STRUCTURE OF THE BOSTON ELEVATED RAILWAY.

By Geo. A. Kimball, President of the Boston Society of Civil Engineers.

[Read before the Society, January 28, 1903.*]

The foundations for the elevated structure of the Boston Elevated Railway were nearly all built in the year 1899. In general the foundations commence 10 or 12 feet below the surface of the ground, this depth being considered necessary for requisite stability and to provide against the danger of being undermined by the ordinary excavations made in the streets and sidewalks for sewers, conduits, foundations for buildings or other excavations which are frequent in city streets.

They are built of Portland cement concrete laid in courses about 2 feet thick, the first course being of such dimensions as are necessary to distribute properly the load on the earth or piles, and vary from 6 feet square in hard material to 12 or more in soft material. The courses are gradually diminished in size, the upper course being 4½ feet square, on which is set a cast-iron pedestal 12 inches high to receive the steel post. Four anchor bolts are built into the upper courses of the concrete, the lower ends being secured to an anchor casting bedded between two of the courses; the upper ends pass through the cast-iron pedestal and lugs on the steel posts where the nuts are attached. Where piles are necessary they are driven in such number and to such depth as to give a stable and safe foundation, and are cut off at grade 5 feet above mean low water, or as much lower as was necessary to get below the ground water level.

LOADS PROVIDED FOR.

Provision was made for the dead load of structure and track system and a live load of 50-ton cars, each 40 feet long. The cars which are actually operated on this structure weigh about 30 tons empty, or about 36 tons crowded, and are 46 feet 3¼ inches in length over all. In designing the structure it was considered best to make provision for much heavier rolling stock than is now used, as it is possible that future developments in methods of transportation may call for locomotive system, or cars that are much heavier than those now in use.

Provision is also made for a horizontal force applied at the rail transversely to the structure of 450 pounds per linear foot of

*Manuscript received March 18, 1903.—Secretary, Ass'n of Eng. Socs.

span, except where such force is exceeded by centrifugal force, in which case the latter is used. The foundations were designed to carry an additional track to the two now in use. This was done for the purpose of having the foundations capable of carrying additional loads which may come upon them on account of introducing, in the future, turnouts, branches, etc.

METHOD OF CALCULATION.

As a post supporting the structure is practically fixed at the top by the cross girder and bracket, and at the bottom by the anchor bolts built into the foundation, the deflection of the column under a horizontal force produces a point of contraflection at the middle of its free length. So far, then, as resistance to horizontal forces is concerned, the foundation and lower half of the post act like a beam fixed at one end, the bottom of the concrete, and free at the other, the point of contraflexure, where the horizontal force acts; the stress at any point in the foundation is, therefore, equal to the combined stresses caused by the vertical force, plus or minus the compression or tension resulting from the bending moment due to the horizontal force.

The transfer of vertical force from one post to the other, due to the moment of the horizontal force about the points of contraflexure of the posts, has been neglected, except where the horizontal force has much exceeded 450 pounds per linear foot of span, or where the ratio of the length of lever arm of the force to the distance between centers of posts has been greater than 1.

STABILITY AND STRENGTH.

The foundations were designed to meet the following conditions:

1. Under maximum vertical and horizontal loads to give a pressure on the earth or piles not in excess of their assumed safe bearing power.

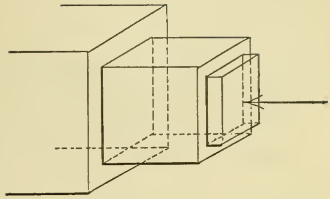
2. Under minimum vertical and maximum horizontal load capable of acting with it, or under the condition of least stability against overturning, to have a factor of 3 against overturning at the edge.

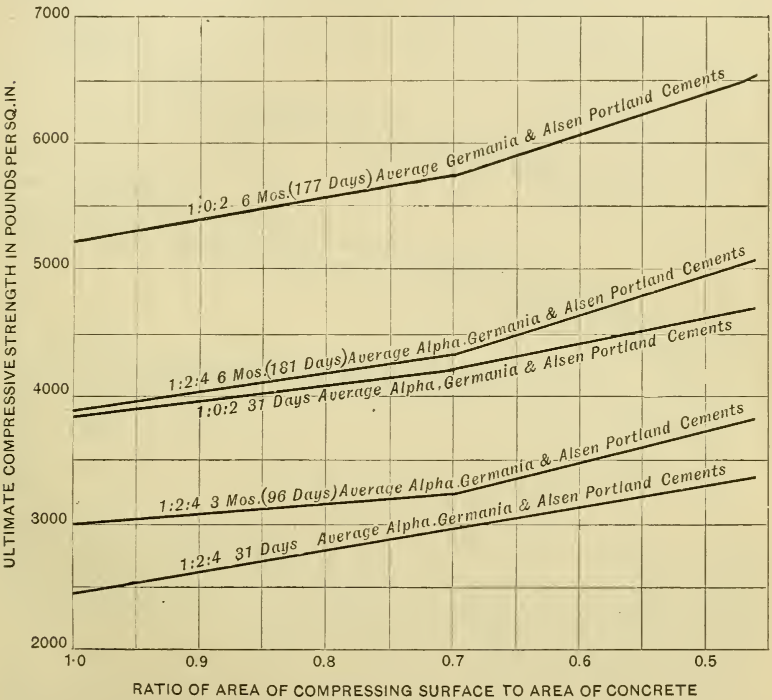
3. Under each of the above conditions, the stresses in the concrete for foundations and anchor bolts not to exceed safe limits.

SAFE STRESSES.

For the determination of safe pressure to use on concrete, a large number of Portland cement concrete 12-inch cubes were prepared and tested by the United States Government at the Water-

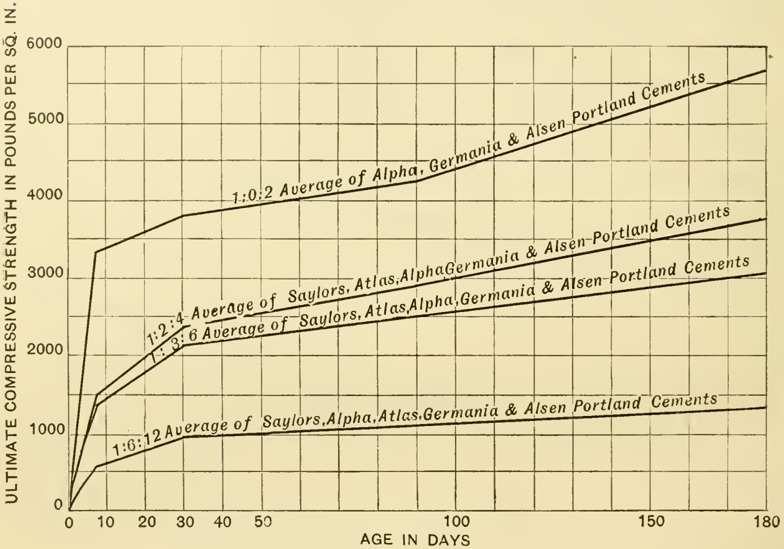
NOTE.—Cubes crushed by placing on one compressive face in one series a die 10″ x 10″, and in another series a die 8″ x 8¼″. In general three cubes were broken with each die for each brand, mixture and age given. The ultimate compressive strength given is in pounds per square inch of the area of the die. The proportions indicated, viz., 1:0:2 and 1:2:4, represent parts by volume of cement, sand and broken stone respectively. Cubes taken out of molds three to four days after making and buried in wet ground until about a week before testing.





TESTS OF PORTLAND CEMENT CONCRETE. AVERAGE ULTIMATE STRENGTH UNDER CONCENTRATED PRESSURE FROM TESTS OF 12-INCH CUBES MADE BY THE BOSTON ELEVATED RAILWAY COMPANY AND TESTED BY THE UNITED STATES GOVERNMENT AT WATERTOWN ARSENAL, MASS., DECEMBER, 1898, TO JULY, 1899.

Tests of Portland Cement Concrete. Average, According to Mixture, from Tests of 12-inch Cubes Made by the Boston Elevated Railway Company and Tested by the United States Government at Watertown Arsenal, Mass., December, 1898, to July, 1899.



Note.—Cubes were crushed at ages of seven days, and approximately at thirty days, three months and six months. From four to six cubes of each mixture of each brand and age were tested and the lines in the diagram are the averages by mixtures of the average results from each brand. Maximum and minimum individual averages usually vary from 10 to 20 per cent. from the general average. The proportions indicated—*e.g.*, 1:0:2, 1:2:4, etc.—represent parts by volume of cement, sand and broken stone respectively. Amount of water used—just enough for concrete to show moisture on surface after ramming.

Materials: Sand, clean and sharp; voids measured loose, 33 per cent.

Broken stone conglomerate from Roxbury, Mass.; various sizes all passing 2½″ ring. Voids measured loose, 49.5 per cent.

Method of Mixing: Cement and sand turned twice dry, then moistened; mortar spread on wet stone and concrete turned twice before ramming into molds. Cubes taken out of molds three or four days after making and, except the seven-day cubes, buried in wet ground until about a week before testing.

Voids, broken corners or other defects in cubes not plastered or patched in any way.

town Arsenal. The detailed results of these tests were published by the United States Government in "Report of the Tests of Metals, etc., at the Watertown Arsenal," for 1899, pages 719 to 781. The average results of these tests are shown on two diagrams, presented herewith, one showing the results of tests with distributed pressure and the other the results with concentrated pressure. The safe pressures used are based on a factor of safety of 10 to 12. The stresses allowed in the concrete have been as follows:

Compressive, varying with the different grades of concrete from 300 pounds to 450 pounds per square inch.

Tensile, not in excess of 30 pounds per square inch.

Maximum tension in anchor bolts, 16,000 pounds per square inch.

As the abutting power of the earth in resistance to horizontal forces has been neglected, the allowed tension in offsets for the bottom course and at base of anchor course, though in general not over 30 pounds per square inch, has been as high as 35 pounds, and, in a few instances, 40 pounds.

SAFE BEARING POWER OF EARTH AND PILES.

In order to determine the character of the ground, borings were made along the line of the structure, except at places where the nature of the soil was known beyond question. Where the best material was encountered, from 2.3 tons to 3 tons were allowed per square foot for foundations of ordinary depth. On a portion of the line, where the foundations rest on clay, which is underlaid by a softer blue clay, a mean pressure of 2 tons per square foot was allowed.

The mean pressure allowed on piles was 10 tons per pile. The total vertical load on the earth or piles, as figured, includes the weight of earth above the concrete included within the vertical planes of the sides of the bottom course.

MATERIALS.

The concrete was composed of American Portland cement, broken stone and sand, usually mixed in the proportion of 1 part cement, $2\frac{1}{2}$ parts sand and 5 parts broken stone; but in practice the concrete for the lower courses was frequently mixed in the proportion of 1 to 3 to 6, and for the upper course a richer mixture of 1 to 1 to 3 was used. This difference in the mixture was made on account of the difference in pressure per square inch between the lower and upper courses.

The anchor bolts are $1\frac{3}{8}$-inch steel, with cold rolled threads. The following are results of the tests for these bolts:

REPORT OF TESTS OF ANCHOR BOLTS BY TENSION AND BENDING.

MADE WITH THE 800,000-POUND TESTING MACHINE AT THE U. S. ARSENAL AT WATERTOWN, MASS., FEBRUARY 2, 1899.

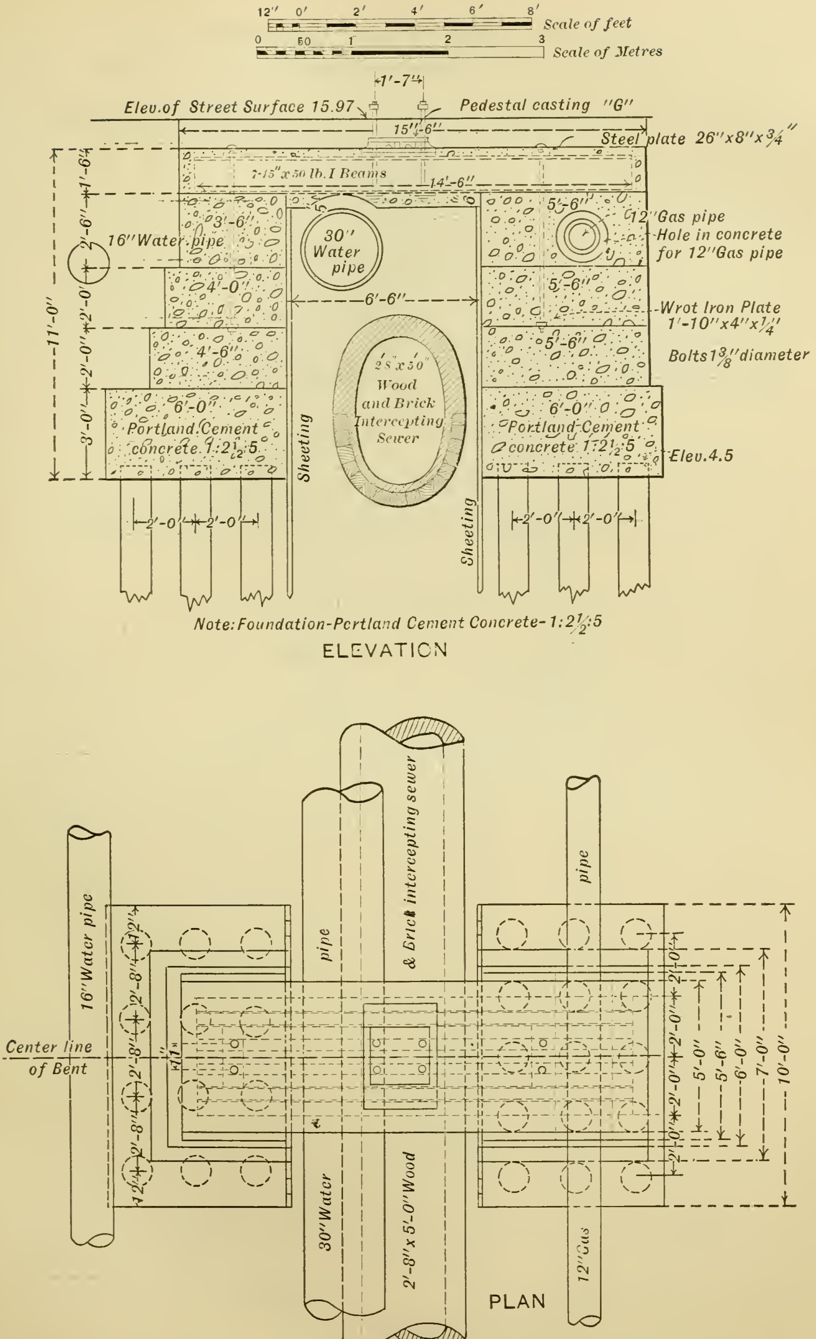
No. of Test.	10 142.	10 143.
Length	6 ft.-4 in.	6 ft.-2 in.
Threads per inch	7	6
Diameters.		
Body of bolt	1.00 in.	1.39 in.
Over thread	1.08 "	1.46 "
Root of thread	.88 "	1.27 "
Sectional areas.		
Body	.785 sq. in.	1.517 sq. in.
Root of thread	.608 "	1.267 "
Elastic limit.		
Total	25,100 lbs.	47,400 lbs.
Per sq. in. of body	31,970 "	31,250 "
Tensile strength.		
Total	42,100 "	83,160 "
Per sq. in. body	53,630 "	54,820 "
" " " root of thread	69,240 "	65,640 "
Elongation in 8 inches.		
Inches	1.75 in.*	3.27 in.
Per cent	21.9 %	40.9%
Area at fracture		(dia. 96 in.) .724 sq. in.
Contraction of area		52.3%
Description of fracture	Fractured at 1st thread. Fine granular, in part silky.	Fractured 2 ft. from threaded section. Silky, cup shaped.
Bending tests	Body of bolt bent 180° and closed down without rupture. * Did not include fractured section.	Body of bolt bent 180° and closed down. A fracture started on tension side.

Correct. (Signed) J. W. REILLY,
(Signed) J. E. HOWARD. *Major, Ordnance Dept. U. S. A. Commanding.*

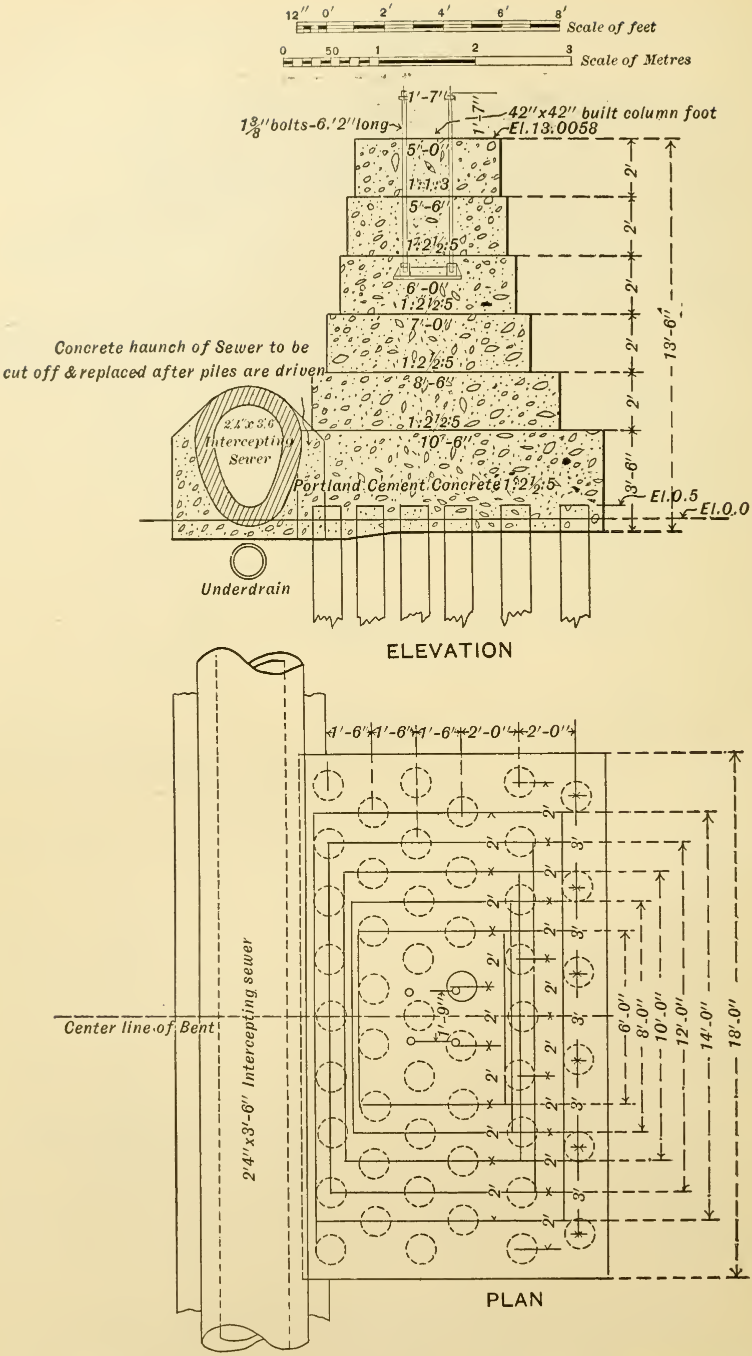
COST.

The difficulties encountered in building foundations were in some cases quite serious, due to soft bottom and the large number of underground structures encountered, such as sewers, drains, water pipes, electric conduits, pipes containing brine for cold storage purposes, steam pipes, etc. A small part of the foundation work in the streets was performed by contract, at the following prices:

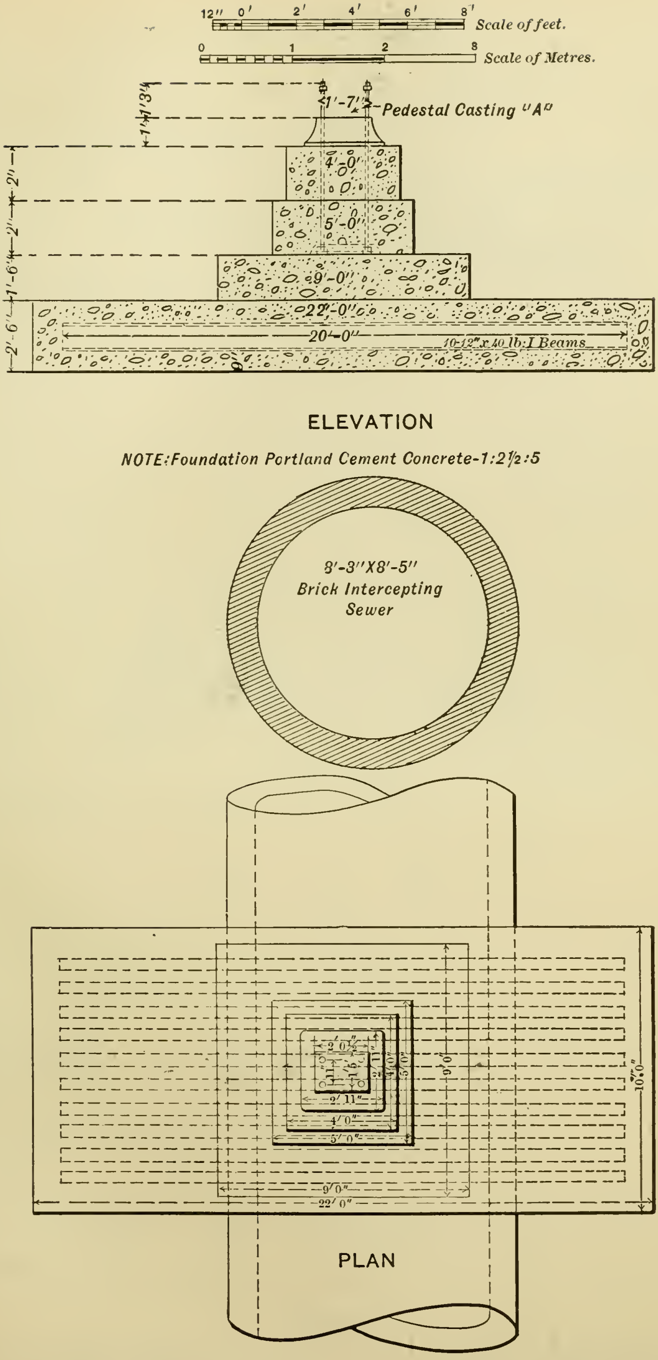
Earth excavation, including refilling, bracing, pumping, etc., per cubic yard	$1.00
Portland cement concrete, mixed 5 to 2½ to 1, per cubic yard	7.00
Surplus earth removed, per cubic yard	.50



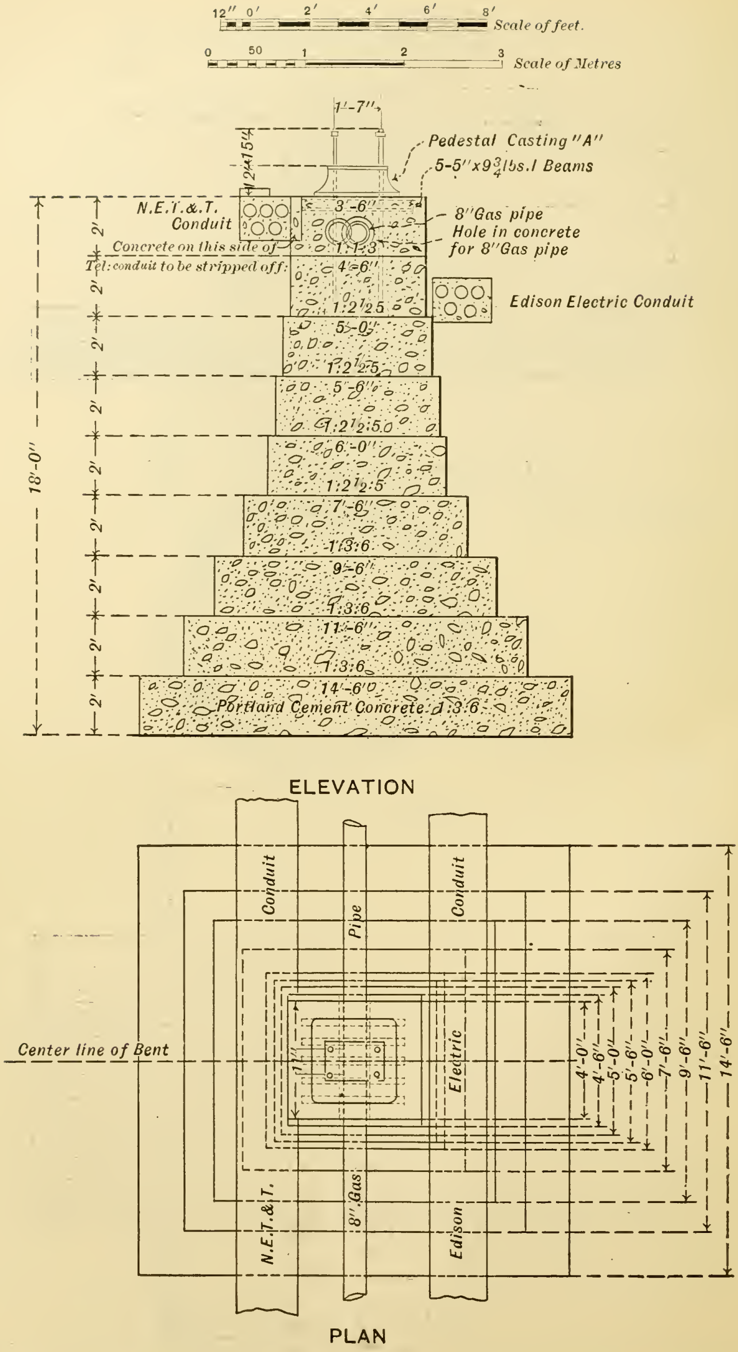
Foundation for the Elevated Structure of the Boston Elevated Railway. Special Design.



Foundation for the Elevated Structure of the Boston Elevated Railway. Special Design.



FOUNDATION FOR THE ELEVATED STRUCTURE OF THE BOSTON ELEVATED RAILWAY. SPECIAL DESIGN.



Foundation for the Elevated Structure of the Boston Elevated Railway. Special Design.

Rock excavation, per cubic yard	$5.00
Setting cast-iron pedestal casting, including teaming, per ton	5.00
Setting wrought-iron anchor bolts, including teaming, per ton	8.00
Lumber used for bracing and left in place, per 1000	15.00
Lumber used for temporary boxing of bolts, per 1000	30.00

The more difficult foundations were built on the percentage basis, where the contractor was employed to furnish all labor and material and was paid a certain percentage for the use of tools and his profit. This proved to be a fair method of building these difficult foundations, where it was necessary to do a large part of the work at night, and where unusual difficulties were encountered which could not be foreseen.

The number of foundations built in the streets was 1133, and of these about one-half cost $260 each, in round figures, or $9.50 per linear foot of double track structure. The remainder averaged about $700 each, or $25.50 per linear foot of double-track structure, the increased cost being due to soft ground and interference with underground structures.

The above amounts include the cost of pedestal castings, anchor castings and anchor bolts, all of which were furnished by the company, averaging $22.30 per foundation; also the cost of moving underground structures (paid directly to other corporations), averaging $18.20 per pier.

The additional cost of concreting around the foot of each post and structure and protecting it with wheel guards or fenders is not included in any of the above figures.

OBITUARY.

George Richardson Hardy.

Member of the Boston Society of Civil Engineers.

[Read before the Society, June 24, 1903.]

In a brief sketch of such a life as that of Mr. Hardy, we find it a simple record of some mathematical achievement and much of the plodding of one who loved his work and was content in the faithful performance of it.

He was the son of William Hardy, and was born June 9, 1848. His death, in April, 1903, shows a span of life covering a little less than fifty-five years. The first ten of these were spent in Hollis, N. H. He then went with his family to live in Malden. Here he grew up, attending the grammar and high schools and graduating from the latter in time to enter the Massachusetts Institute of Technology in the fall of 1866. There he took a four years' course in civil engineering, and, military drill being then required, he was, during one year, major of the battalion. He continued, however, to be resident of Malden, and it was here, also, that he found his bride. He married Ella C. Foljambe, the daughter of the late Samuel W. Foljambe, D.D., then pastor of the Baptist Church, in which his own father had been for many years an influential deacon. She it is that to-day mourns the loss of a faithful husband, while four children—three daughters and one son—miss the presence of a loving father. And outside of his home he had the rare and happy faculty of winning everywhere staunch and true friends. Men in business and society grew to love their comrade. Perhaps something of the secret of this is explained in the generous tribute of Mr. Otis F. Clapp, now city engineer of providence, who writes: "He had a very cheerful disposition, was dignified and gentlemanly in his bearing, with a high standard of moral principle, and was much liked by all who were brought into contact with him."

In the season of 1868, in the vacation, he was with Mr. Clapp, making surveys for establishing street lines and grades for the central portion of the city of Providence.

In 1870 he was employed on the Northern Pacific Railroad on preliminary and constructive work in Minnesota, as assistant engineer.

In 1871, for one year, he was engaged in mercantile employment.

In 1872 he was engaged in general engineering work under the firm name of Hardy & Kimball, civil engineers, located in Boston.

In the spring of 1873 he became connected with the Boston and Albany Railroad as superintendent of construction, in charge of a new elevator, shops, depots, etc. As one crosses the harbor on any of the many ferries plying between Boston and East Boston they may see, looming as a lofty monument of painstaking industry and skill, the great grain elevator. Thirteen years he remained with the Boston and Albany Railroad, passing from the youthful beginner into the man of mature business qualifications, along the line of work he had grown to so thoroughly enjoy. He was made assistant chief engineer and had experience in the maintenance of way, as well as designing and constructing new bridges, buildings, signals and other structures, and the work of extending the line and enlarging the facilities for four-track work, etc. One of his special accomplishments was the planning of the yards and track approaches to and construction of the Union Station at Worcester.

In 1886 he went to the Lake Shore and Michigan Southern as assistant chief engineer. In 1887 he was appointed chief engineer of that road. After leaving there he was engaged on the New York, New Haven and Hartford Railroad from December, 1887, to August, 1889, as assistant engineer on various surveys.

He next engaged with the Westinghouse Electric Manufacturing Company, and was much interested in the introduction of the interlocking system of switches and signals in New England, having prepared and read before our Society April 17, 1886, a very interesting paper on this subject.

From January, 1893, to September, 1897, he was assistant engineer of construction with the New York, New Haven and Hartford Railroad on special work, including the immediate supervision of the four-track construction work on the New York division through the city of Stamford and for several miles on each side of that city.

From September, 1897, to July, 1899, he had the immediate supervision of the elimination of grade-crossing work in Suffolk and Norfolk Counties, and from July, 1899, to time of decease he had the immediate supervision of the elimination of grade-crossing work at Blackstone, Auburn, Whitins and Readville. This included the construction of the extensive shops and tracks at Readville; also preliminary work pertaining to the proposed elimination of grade crossings in Worcester, Attleboro, Pawtucket and Taun-

ton. The work at Readville called for a great deal of care and study, on account of quicksand, when founding the arch, and the construction of very extensive shops. The arch has been reputed to have the largest single keystone in the world to-day. In all of this he had been stirred to an ardent enthusiasm and took much pride in its satisfactory completion.

Mr. Hardy was social by nature, and especially loyal to such associations as promoted his own or other branches of scientific advancement. He was elected treasurer of the International Road-masters' Association, organized in Boston March 25, 1879. This association was the first of the kind to be organized in this country, and he manifested a great interest in it and was a regular attendant for several years. He joined the Boston Society of Civil Engineers June 8, 1874, and the American Society of Civil Engineers November 7, 1888.

In the social gatherings of his home city one of the most prized links was a membership held with the Union League, of New Haven, Conn., for about fifteen years, and he served on the Executive Committee of the League. Among the older members were many who learned to love his rare good nature and the keenness and breadth of his intellect.

Drawing these remarks to a close, we will simply add that he was an excellent mathematician, often engaged in working out new and simple solutions to involved problems, and that he was for many years in charge of very important works, which show his engineering ability. These, indeed, are his best monuments.

L. B. Bidwell.
E. K. Turner.
Walter Shepard.

Association of Engineering Societies.

Vol. XXX. JANUARY, 1903. No. 1.

PROCEEDINGS.

Engineers' Society of Western New York.

Annual Meeting, Buffalo, December, 2, 1902.—The meeting was called to order in the rooms of the Society, 433 Ellicott Square, at 4.30 P.M., by the President. Members present, Messrs. Haven, Tutton, Norton, Hoffman, Eighmy, Knapp, Murphy, Babcock, Bassett, March and Roberts.

The minutes of previous meeting were read and approved.

Application for membership from Chas. H. Smith was received from the Executive Board and ordered to letter ballot.

Mr. March, from the Committee on "Abatement of the Smoke Nuisance," reported progress.

The report of the Secretary was then read and on motion the same was ordered received, filed and referred to a special committee to examine books and accounts.

The Treasurer said that his report would be ready in a few days.

The President appointed a special committee to examine both reports, namely, Mr. A. W. Hoffman, who was directed to report to the Executive Board.

The Librarian being out of town no report was received from him.

Mr. Hoffman and Mr. Murphy were appointed tellers to canvass the ballots cast for officers of the Society for 1903.

The tellers reported that the following persons had received a majority of the votes cast for the several offices:

For President—Samuel J. Fields.

For Vice-President—George N. Norton.

For Director—Soren M. Kielland.

For Secretary—Lee W. Eighmy.

For Librarian—William A. Haven.

For Treasurer—George B. Bassett.*

The above-named gentlemen were declared by the President duly elected.

*Mr. Bassett resigned the office of Treasurer December 11th, and, in accordance with the By-Laws, the Executive Board appointed Mr. Frank N. Speyer as Treasurer.

There being no further business the meeting adjourned until 8 P.M., at the Niagara.

The adjourned meeting was called to order at 9.30 P.M. There were present the following named persons in addition to those present at the afternoon meeting, viz, Messrs. Carleton, Thorn, Dark, Morse, C. M., Morse, G. F., Johnson, Wilson, Lyon and Caines, members, and Messrs. Francis G. Ward and C. P. MacArthur as visitors.

The President referred briefly to the circular that he had sent out with the call for the annual meeting, and stated that the subject for discussion was the bill now before the House of Representatives relating to the Metric system. He then called upon Vice-President Chas. H. Tutton, who said:

"Gentlemen, I was requested to talk a little on the metric system this evening, and I take the liberty of placing it in the form of a short paper. Probably there are some of you who do not know what a meter is. Here is a rule that came from Paris,—with all the different divisions. The smallest division on that rule is the millimeter; the next is the centimeter; the joint is a decimeter, and the full length of the rule is a meter."

Mr. Tutton's paper will be found printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The following resolution was offered, duly seconded, and unanimously adopted:

"*Resolved,* That the Secretary of the Society notify our members of Congress that, in the opinion of the members of the Engineers' Society of Western New York, the passage of any bill making the metric system compulsory in this country is premature, and such action should not be taken without full and free discussion throughout the country."

This ended the discussion of H. R. bill 123.

Mr. Bassett, of the Committee on the Abatement of the Smoke Nuisance, said that the committee expected to be ready to make a final report at the January meeting.

MR. TUTTON.—As this is our Annual Meeting, and I believe that our President occupies the chair for the last time, I desire the Society to express a vote of thanks to him for his services for the past three years. He has held the office longer than any previous incumbent. I believe he has been found perfectly satisfactory in every way, and I move that the Society give him a vote of thanks, and retire him with very much,—what would you call it?—gratefulness or graciousness?

Motion seconded.

MR. NORTON.—It is moved and seconded that this Society extend to our retiring President its appreciation for the great service which he has rendered to the Society, and our thanks for his labors in building it up. All those in favor of the motion manifest it by rising.

Motion carried.

Mr. Haven made a few remarks in reply and thanked the Society for its continued confidence in him, as shown, by promoting him to the office of Librarian. He said that he would try to make a full report on the state of the Society at the January meeting, and meanwhile he was very glad to congratulate the Society on its good condition generally and the prospect of its membership increasing to one hundred during 1903.

He said he had received a letter from Mr. Samuel J. Fields, the newly-elected President, saying that he would accept the office if elected; that even

if he lived in St. Louis during 1903, he could be of service to the Society as its representative at the Exposition.

Mr. Dark then, in a few complimentary remarks, proposed the health of the newly-elected President Fields, which was drank standing.

Mr. Kielland, in compliment to the Commissioner of Public Works of Buffalo, proposed the health of Colonel Ward, and, after a kind reply from Colonel Ward, the meeting adjourned at midnight.

GEORGE T. ROBERTS, *Secretary.*

REGULAR MEETING, BUFFALO, N. Y., JANUARY 13, 1903.—Held at their rooms, 533 Ellicott Square, Tuesday, January 6, 1903.

Meeting was called to order by the Vice-President, Mr. Tutton, with the following members present: Haven, Knapp, Norton, Bassett, Babcock, Speyer, G. F. Morse, Meyer, Golden, Eighmy, Murphy and Caines. The minutes of the Annual Meeting were read and approved. The Executive Board reported that Mr. Bassett having resigned as Treasurer, they had, as per Article III, Section 2, of the Constitution, appointed Mr. Frank N. Speyer as Treasurer; also that they had elected Walter L. Golden as a temporary member; also that they had voted to allow to any member, junior or associate, twenty per cent. of the gross receipts for advertisements procured by them for the JOURNAL of the Association.

Applications for admission as associates from H. P. Burgard and Wm. H. Lamme were read, and it was voted that the applications be approved and submitted to a letter ballot. The Chairman announced that Mr. Chas. W. Smith had been elected as a member.

Mr. Louis H. Knapp, chairman of the committee to consider the subject of "The Abatement of the Smoke Nuisance in the City of Buffalo," read a final report of the committee, whereupon it was voted that the report be adopted and that copies be sent to the newspapers of Buffalo for publication, also to the Society for beautifying Buffalo, and that the committee be discharged.

The Acting President announced that he had appointed as Committee on Library, W. A. Haven, Librarian, Chairman; Mr. Louis H. Knapp and Mr. Geo. H. Norton.

Mr. Haven proposed in writing an amendment to the Constitution, viz, "To amend Section 9, Article II, so that it will read as follows: All classes of membership are entitled to vote and hold office."

This was read and seconded by two-thirds of the members present, and laid on the table until the next regular meeting.

The retiring President, Mr. Haven, made a short address as follows:

ADDRESS OF THE RETIRING PRESIDENT.

In the notice for the regular meeting of the Engineers' Society of Western New York to be held January 6, 1903, it was stated that the retiring President would make an address. At the meeting, Mr. Haven, the retiring President, made an address, but as it was not read from manuscript, and as there was no reporter present, it cannot be reproduced.

He began by saying that the recent addresses of retiring Presidents of similar societies had been usually upon the subject of the engineering works in their immediate charge, but that he did not think the Society would be either interested or instructed by an account of the work in his charge during the past three years.

He then stated good and sufficient reasons why he should not at that time discuss any of the engineering problems in and about Buffalo, such as the Union Station, Hamburg Turnpike, South Buffalo floods, sea wall strip, improvement of new harbor, proper drainage of the Western New York frontier from Smokes Creek to La Salle, which would insure perfectly pure water at the present water works crib, and other great works. The reasons given by Mr. Haven seemed to the members present adequate for his not discussing any of these subjects. The retiring President then spoke for ten minutes upon some of his engineering experiences during the first four years of his professional life, especially during the construction of the Northern Railroad of New York.

He then said: "The report of your Secretary is quite interesting. He tells you that we have been unable to get a paper read at every meeting because the members of the Society are all too busily engaged in their own business to prepare papers for the Society. I sincerely congratulate you upon this fact, but I am very sorry to see, by a former statement in the report, that twenty-two of you were so very busy during the past year that you had no time to make checks, or to pay the money for your annual dues. This has been a source of considerable embarrassment to your executive officers, for the Treasurer reports that the unpaid bills in his hands could easily have been paid if you had been prompt in the payment of your dues.

There is one matter which I wish to bring particularly before your attention, and that is that with very slight efforts on the part of the retiring Secretary and the Librarian, advertisements for the JOURNAL have been procured to the amount of $128, ninety per cent. of which was added to the current funds in the hands of the Treasurer. This amount was nearly enough to pay the entire expense of the Association dues for the year 1902. I hope that in future years there will be a considerable balance to the credit of the Society from this source of income.

It is quite important, for the continued success of the Society, that the Secretary should remain in office longer than one year. I find by reading the minutes of the Society that since its organization in the fall of 1894 there have been seven Secretaries. The principal work and worry of a Secretary comes during the first two months of his term of office. After that it is routine work. As it is now he hardly gets accustomed to his duties before he goes out of office.

I herewith submit the summary of the report of the Treasurer:

SUMMARY OF THE REPORT OF THE TREASURER, DECEMBER 9, 1902.

GENERAL FUND.

Receipts—G. R. Sikes, retiring Treasurer	$8.24	
Receipts—G. T. Roberts, Secretary	624.75	
Paid bills		$637.82
December 4, fund overdrawn	4.83	
	$637.82	$637.82

LIBRARY FUND.

Receipts—Subscriptions	$46.00	
Receipts—Permanent Fund	100.00	
Paid binding bills		$68.40
Bal. in fund		77.60
	$146.00	$146.00

PERMANENT FUND.

Receipts—G. R. Sikes, retiring Treasurer	$279.00	
Receipts—Interest Erie Co. Sav. Bank	9.64	
Receipts—Initiation fees, 1902	33.00	
Paid Library Fund		$100.00
Bal. in fund		221.64
	$321.64	$321.64

STATEMENT OF CASH.

General Fund overdrawn		$4.83
Bal. in Library Fund	$77.60	
Bal. in Permanent Fund	221.64	
Cash in Fidelity Bank		3.77
Cash in Erie Co. Savings Bank		290.64
	$299.24	$299.24

Respectfully submitted,

(Signed) G. B. BASSETT, *Treasurer.*

I also submit a statement showing for what purposes the money has been expended:

Amounts expended in 1902, which were chargeable to expenses of 1901, viz:

Association dues, 2d and 3d quarters of 1901	$87.00
Postage, typewriting, stationery, printing, etc.	37.34
Rent, for November, 1901	23.00
Annual dinner of 1901	27.00
Total	$174.34

Amounts chargeable to 1902:

Association dues, 4th quarter of 1901, and 1st, 2d and 3d quarters of 1902	$147.50
Rent December, 1901, to August, 1902, inclusive	207.00
Postage, stationery, etc.	34.71
Reporting meeting and typewriting	32.22
Printing	21.00
For Library—	
Subscriptions and purchases	20.05
Binding	69.40
Total	$531.83

Now, that you have, by your vote, provided for an annual expenditure for binding the various publications, I trust that in the course of two or three years your Library will be of greater use to you than it is now, and that it will be known as the best reference library for engineering in Western New York.

I am glad that there is now a Committee on Library, with whom the Librarian may readily consult.

REPORT OF THE SECRETARY FOR 1902.

MR. WM. A. HAVEN, PRESIDENT ENGINEERS' SOCIETY OF WESTERN NEW YORK, BUFFALO, N. Y.

Dear Sir,—I submit herewith the following report:

MEMBERS.

December 1, 1901, there were:

Honorary member	1
Members whose dues were paid	60
Members whose dues were unpaid	6
Associates whose dues were paid	9
Associate whose dues were unpaid	1
Junior whose dues were paid	1
Juniors whose dues were unpaid	2
Total	80
During the past year:	
Members have been elected	5
Associate has been elected	1
Junior has been elected	1
Increase by election:	
Members	5
Associate	1
Junior	1
Total	7
Decrease:	
Death	1
Resignations	2
Total	3
Net increase	4
Total December 1, 1901	80
Total December 1, 1902	84
Honorary member	1
Members whose dues are paid	53
Members whose dues are unpaid	15
Associates whose dues are paid	7
Associates whose dues are unpaid	4
Juniors whose dues are paid	1
Juniors whose dues are unpaid	3
	84

MONEYS.

Total amount received by the Secretary from members between December 1, 1901, and December 1, 1902:

Entrance fees	$33.00
Dues	495.00
Key deposits	1.75
From advertisements for JOURNAL	128.00
	$657.75
Amount deposited with Treasurer	657.75
Amount on hand	0.00

MEETINGS OF THE SOCIETY.

Eight meetings of the Society have been held since December 1, 1901, with an average attendance of twelve.

During the past year the following very interesting papers were read before the Society:

"Modern Street Railroad Construction," by C. C. Lewis.

"Pavements in General," by C. E. P. Babcock.

"Dock Construction in and Around Buffalo," by S. M. Kielland.

"Abatement of the Floods in South Buffalo," by Geo. H. Norton.

MEETINGS OF THE EXECUTIVE BOARD.

Twelve meetings of the Executive Board have been held since December 1, 1901, with an average attendance of five.

The largest attendance has been at the meetings at which we have had papers presented, and although I endeavored to have a paper at each meeting, I found it impossible to do so.

The members are usually too busy to write them, and as a rule, think that a lengthy address is necessary. I believe that a short address on an interesting subject would provoke discussion and tend to improve the members, as well as a long one.

I respectfully request that the President appoint a committee to examine the books of the Secretary before they are turned over to the newly-elected officer. Respectfully submitted,

GEORGE T. ROBERTS, *Secretary.*

At 10 o'clock the meeting adjourned.

(Signed) LEE W. EIGHMY, *Secretary.*

Louisiana Engineering Society.

NEW ORLEANS, LA., JANUARY 10, 1903.—The Annual Meeting of the Louisiana Engineering Society was held this day at 8.30 P.M.; President Theard in the chair, and Secretary Lawes and fifteen members present.

After routine business the annual report of the Board of Directors was read. It is as follows:

To the Members of the Louisiana Engineering Society.

GENTLEMEN:—As required by the Constitution of the Society, your Board of Directors submits the following report:

During the year another attempt was made, during the session of the State Legislature, to pass the "act regulating the practice of the engineering profession." Beginning with most favorable prospects, the measure met with ultimate defeat, in what manner is well known to the Society. In furtherance of the measure, an expense of $52.15 was incurred by the Society in sending representatives to Baton Rouge.

At the expiration of the lease of the quarters, 712 Union street, on the 1st of October last, it was decided by the Board to secure other quarters more suited to the needs of the Society and at less rental. The present rooms were secured, and we feel that the change has been most advantageous.

The annual outing was given during the year, to Laurel, Miss., and was unqualifiedly successful in every way, except financially. The application for tickets was disappointingly small, and, as a result, the Society had to draw on its surplus funds to meet the expense. The outings should be, it seems to the Board, a matter of interest to each and every member, and,

when decided on, should receive their earnest support. If all members took but a part of the interest that the more zealous do, there would be no trouble about the financial part of these excursions.

During the year the address of the retiring President, Mr. Kerr, and two technical papers were read before the Society. The papers were "Rainfalls" by President Theard, and "Notes on Railroads and Railroad Construction" by Mr. Wright, the Vice-President. Mr. Kerr's address and Mr. Theard's paper were published in the Journal.

As a part of this report is submitted the Treasurer's report.

The finances of the Society are in good shape, notwithstanding but a small cash balance appears. By reference to the Treasurer's report for 1901, wherein a table of the annual debits and credits are shown, it will be seen that for nearly every year since the organization of the Society its expense has exceeded its income, and in this way the large balance on hand at the end of the first year has steadily decreased.

This would seem to indicate that the finances are not in good shape; but in considering the different items of the table above referred to, it is seen that to the outing items is due the excess of expense. Therefore, we have but to eliminate this item, and the income of the Society will be amply sufficient for its needs. This year an unlooked for item of expense was for installation, but as the saving in rent will more than doubly offset this in one year, it need not be considered, except as a temporary inconvenience.

As the report of the Treasurer gives in detail how the funds of the Society have been handled, we give but a summary, as follows:

Balance on hand from last year	$202.62
Collected since	1,064.40
Total	$1,267.02
Expenditures	1,234.24
Balance on hard	$32.78

The Secretary's report is also submitted as part of this report. It shows a total membership of sixty-eight, being four in excess of that of last year. The details of the increase is given in the report.

The report of the House Committee not received.

The report of the Library Committee is herewith and made part of this report.

A committee was appointed during the year to take up the matter of an exhibit by the Society at the Louisiana Purchase Exposition to be held in St. Louis in 1904. A report from this committee is herewith and made part of this report.

In the matter of compensation to the Secretary, referred to the Board at the last meeting of the Society, we would state that a motion was passed by the Board recommending that some compensation be made, the amount to be such as the Society can afford.

Respectfully submitted,

The Board of Directors.

Election of officers was then had and the following gentlemen chosen:

President—Alfred Raymond.

Vice-President—W. B. Wright.

Secretary—J. W. Armstrong.

Treasurer—Gervais Lombard.

Member of Board of Managers, Association of Engineering Societies—Alfred F. Theard.

Directors—A. C. Duval, Prof. J. M. Ordway.

Mr. Theard, the retiring President, then read his annual address, of which the following is an abstract:

"Under the present laws any man can set up as a civil engineer. This is wrong. In every other profession, special training is necessary, and in engineering the same should be the case. The engineers of the State should be protected from the unfair competition of the quack. The public, also, should be protected. One of two things can be done to accomplish this, shut out the quack or specify competent engineers.

"At the last Legislature a bill was introduced and was indefinitely postponed."

In narrating this incident of the defeat of the bill, President Theard grew warm, declaring it unjust that, with an attempt at wit, the efforts of the engineers should thus come to nothing. President Theard said that he did not wish to criticise the greatness of the Legislators, if indeed there was any greatness, but he did want to go on record as favoring reform in laws governing the practice of civil engineering. He still hoped that the Legislature would see fit to pass a suitable bill.

In closing, Mr. Theard thanked Secretary Lawes and the Board of Directors for help given during the year, declaring that he was fortunate in having been co-laborers with them.

He then introduced the newly-elected President, Mr. Raymond.

The Society, by vote, extended thanks to the retiring Board and Secretary and to President Theard for his able paper and eminent service.

Adjourned. G. W. Lawes, *Secretary.*

Engineers' Club of Minneapolis.

162d Meeting, Minneapolis, December 18, 1902.—Called to order in the County Commissioners' rooms by President Hoag.

The meeting was devoted to the consideration of gasoline engines.

E. C. Oliver, instructor in mechanical engineering at the State University, read a paper on "Theory of Operation." (To be published in the Journal.)

N. E. Brown on the "Gasoline Engine for Automobiles."

O. B. Kinnard on "Gasoline Engines for Farm Use."

The Club at this meeting began an enthusiastic move for a good library and suitable accommodations for same.

Edward P. Burch, *Secretary.*

163d Meeting, Minneapolis, January 26, 1903.—Called to order by President Hoag, in the County Commissioners' room, Court House.

Sixteen men, as follows, were elected to active membership: Ralph D. Thomas, H. G. Tregillus, C. A. Glass, O. H. Nordenson, H. S. Cook, Wm. W. Bright, S. W. Tarr, Adolph E. Eberhart, Melville O. Stone, E. C. Loetscher, A. P. Sprague, Wm. P. Cowles, Chas. G. Olson, John H. Hall, J. G. Anderson, J. C. Moore.

The name of A. G. Holt, division engineer, Chicago, Milwaukee and St. Paul Railroad, was proposed for membership.

The report of the President for the year referred briefly to the growing prestige of the engineering profession; that at the present time there are over fifty colleges and universities that pay especial attention to the course of three or more branches of engineering.

The report of the Treasurer and Secretary was as follows:

Annual Report of the Treasurer, 1902.

RECEIPTS.

Cash on hand January 3, 1902	$53.35
Received from 61 members, dues	183.00
Received from back dues	4.00
Total receipts	$240.35

EXPENDITURES.

Printing and expenses as shown by vouchers	$67.00
Journal of the Association bills	71.00
Total expenditures	$138.00
Balance, cash on hand 1902 account	102.35

All bills received have been paid. One member has not paid 1902 dues.

Annual Report of the Secretary.

This being the annual meeting, it becomes the duty of the Secretary to make a report of the preceding year.

The Club held meetings in 1902 as follows:

January 27th, 153d meeting. Devoted to a paper on "Asphalt and Brick Pavements," by Geo. W. Sublette, and a paper on "Sidewalk Construction," by W. F. Dealing.

February 17th. Meeting devoted to a "Consideration of the Water Supply of Minneapolis." Discussion by Dr. L. M. Crafts, Wm. R. Hoag, J. T. Fanning, Dr. C. A. McCollum and others.

March 24th. Meeting devoted to the new Chamber of Commerce building. Papers by C. L. Pillsbury, W. W. Ensign and Wm. Robertson.

April 25th. Meeting devoted to a paper by W. D. Wheeler, on "Railroad Maintenance of Way," and a paper by F. E. Rice on the "New Milwaukee Short Line Bridge at Minneapolis."

The May 19th meeting was devoted to the subject of "Good Roads," by Geo. W. Cooley.

The June 18th meeting was in the nature of a visit by the Club to the new city water pumping station then under construction.

The July 18th meeting was in the nature of a trip by the Club to the old city water pumping station, the C. A. Smith Lumber Co.'s mill, and to the city garbage crematory.

The September 13th meeting was in the nature of a trip to Sandstone, Minn., where the Club inspected the quarries of the Kettle River Quarries Co.

The October 25th meeting was on a trip to Red Wing, Minn., to inspect the Red Wing Sewer Pipe Co.'s works.

The December 18th, or 162d meeting was given to papers on "Gasoline Engines" by E. C. Oliver, N. E. Brown and O. B. Kinnard.

We have thus held eleven meetings. The attendance has been large, averaging about thirty-five members and visitors. Our programs and visits have been interesting. The Program Committee, H. B. Avery, chairman, have worked hard to promote interest in our meetings.

At the beginning of the year we had twenty-nine members. Two have resigned during the year. No one has been dropped by the non-payment of dues, although one member has had notice served on him as required by the Constitution.

During the year thirty-five members have been elected by the Club and have qualified as active members by payment of their dues. We have, therefore, at the end of the year 1902 sixty-two members, a net gain of thirty-three. In other words, our membership has more than doubled. The Membership Committee have been working.

The Club has grown in membership. It would be well to have the Membership Committee discourage those who by design or construction are not fitted for membership. We should not be exclusive (for we remember that at the end of the year 1900 we had but fifteen members), yet we should see that all new members are a credit to the Club, and are workers. Some Clubs compel each member to contribute to the program each year, or pay to the Treasurer double assessment. The idea has merit.

The Club feels the need of a good library more than any other one thing. No progress has been made during the year.

With reference to dues for this year, the Secretary recommends that the dues remain at $3 per year, but that the additional sum of $1.50 be assessed members who desire the JOURNAL of the Association. Many of our members rightly consider that money spent for the JOURNAL ($2 per year) is wasted and should be used on our library; yet many of our members desire to have the JOURNAL. The above plan will suit the members and still give the Association of Engineering Societies a good JOURNAL subscription list and the support of our members.

The Secretary thus closes two years' work. He desires that this combined pleasure and work be given to another, as a matter of right. The Secretary in this Club is the real manager of the Club, and shapes its policy. New ideas and new plans from his successor cannot but be of value to the Club.

Respectfully submitted,

EDWARD P. BURCH, *Secretary.*

The election of officers for 1903 resulted as follows:

President—H. B. Avery.

Vice-President—Edward P. Burch.

Secretary—James B. Gilman.

Treasurer—B. H. Durham.

Librarian—J. E. Carroll.

Representative to the Association of Engineering Societies—W. W. Redfield.

Members of Finance Committee.—J. M. Tate and C. L. Pillsbury.

The program of the evening consisted of talks on engineering matters, illustrated with stereopticon views.

Edward P. Burch presented thirty views of the hydraulic and electrical engineering, largely photographs and reproductions from tracings of the lower power house at St. Anthony Falls, and the distribution of this power to Minneapolis and St. Paul. He stated that the method of distribution by high voltages in underground cables to sub-stations where the power was transformed and converted for use on the street cars was now becoming a common and is the modern system. The plant described had a capacity of 10,000 horse power, but it had long since been found too small for the elec-

tric railway service in Minneapolis and St. Paul, due to the use of twenty-one-ton cars in place of seven-ton cars.

Professor Hoag showed fifty views of bad and good roads in this country, and showed also views of road construction at the State Fair grounds; also local roads and particularly the local Osseo road.

F. E. Rice showed twenty-five slides of the new Milwaukee railroad bridge at Minneapolis, taken during construction in 1902. The matter was of great interest to the Club.

EDWARD P. BURCH, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, JANUARY 2, 1903.—Called to order at 8.30 P.M., by Past-President Grunsky.

The minutes of the last regular meeting were read and approved.

The Nominating Committee, appointed at the regular meeting of December, presented the following report:

SAN FRANCISCO, CAL., January 2, 1903.

To the President and Members of the Technical Society of the Pacific Coast.

Your Committee on Nominations for the ensuing term desires to report the following:

For President—D. C. Henny.

For Vice-President—J. L. Le Conte.

For Secretary—Otto von Geldern.

For Treasurer—E. T. Schild.

For Directors—H. d'H. Connick, S. G. Hindes, A. Lietz, C. Uhlig, Geo. H. Wallis.

Respectfully submitted for the committee,

C. E. GRUNSKY.

The Secretary was instructed to prepare the ballots for the election of officers in accordance with this report, and the Chairman appointed Marsden Manson and F. C. Herrmann tellers for the Annual Meeting.

Mr. W. H. Smyth thereupon read a paper entitled, "A New Type of Heat Motor," which was discussed and stenographically reported. The paper was illustrated by numerous lantern slides illustrating the gradual development of this type of motor, taken from actual experiments carried on by the author.

The paper proved of considerable interest, and the thanks of the Society were extended by vote to Mr. Smyth for the careful preparation of the novel and interesting subject.

The Secretary announced that after a count of ballots the following names had been elected to membership: Leon S. Quimby, civil engineer, of San Francisco, and Morris Kind, of the Pacific Portland Cement Company, of Suisun.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

ANNUAL MEETING, SAN FRANCISCO, JANUARY 16, 1903.—Called to order at 8.30 P.M., by Past-President Grunsky.

The tellers appointed by the Chair reported and were instructed to open the ballots that had been received by mail up to the time of opening the meeting. The result of the ballots stood as follows:

Total number of votes cast, 35.

For President—D. C. Henny, 35 votes.

For Vice-President—L. J. Le Conte, 35 votes.

For Secretary—Otto von Geldern, 35 votes.

For Treasurer—E. T. Schild, 35 votes.

For Directors—H. d'H. Connick, S. G. Hindes, Adolf Lietz, Carl Uhlig, George H. Wallis, each 35 votes.

The Chairman thereupon declared the ticket elected and instructed the Secretary to notify the candidates of their election, and to call a meeting of the Directory for Friday, February 6th, at 4.30 P.M. for the purpose of organizing the new Board, and to discuss a policy and line of activity for the coming year.

The Secretary read the reports of the Secretary and Treasurer, which were ordered received and placed on file. The bills and receipts were submitted and referred to the Finance Committee for approval.

Meeting thereupon adjourned. OTTO VON GELDERN, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, JANUARY 14, 1903.—A special meeting of the Boston Society of Civil Engineers was held in the Society's library at 8 P.M.; Vice-President Frederick Brooks in the chair. Twenty-eight members and visitors present.

Mr. Frank S. Hart read a paper entitled, "A Comparison of the Methods of Estimating Quantities of Soil Stripping from Water Supply Reservoirs."

Mr. Charles A. Bowman, division engineer, Metropolitan Water Works, read a paper describing the method used in estimating soil stripping for the Wachusett Reservoir. A general discussion followed in which Messrs. H. A. Miller, George B. Francis, N. S. Brock and W. W. Patch and others took part.

Adjourned. S. E. TINKHAM, *Secretary.*

BOSTON, JANUARY 28, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 P.M.; President George A. Kimball in the chair. One hunded and thirty-six members and visitors present.

The records of the last regular meeting and of the special meeting of January 14th were read and approved.

On motion of Mr. F. W. Hodgdon, the President was requested to appoint a committee of three to report to the meeting the names of five members to serve as a Committee to Nominate officers for the ensuing year. The President appointed as that committee, Messrs. F. W. Hodgdon, E. W. Branch and W. S. Johnson.

Later in the evening this committee reported the following names as members of the Nominating Committee: Messrs. Leonard Metcalf, Arthur L. Plimpton, Arthur T. Safford, Henry D. Woods and T. Howard Barnes.

On motion of Professor Swain, the report was accepted and the members named chosen as the Committee to Nominate officers.

The President announced the death of Prof. Henry Mitchell, a member of the Society, which occurred on December 1, 1902, and by vote the President was requested to appoint a committee to prepare a memoir.

On motion of Mr. Main, Mr. Henry Manley was appointed a committee with full powers to make the necessary arrangement for the annual dinner of the Society.

On motion of Mr. Higgins, the thanks of the Society were voted to Col. Murray B. Clement and other officials of the American Waltham Watch Company, for courtesies extended this afternoon to members of the Society on the occasion of the visit to the works of that company.

In the absence of the committee, Messrs. Charles W. Sherman and Henry D. Woods, the Secretary read the memoir of Frank E. Fuller prepared by them.

The discussion of the evening was on "Foundations for Buildings and Engineering Structures."

Mr. J. R. Worcester read the first paper entitled, "Boston Foundations," which was discussed by Messrs. J. E. Cheney, Henry Manley, J. P. Snow, J. W. Rollins, Jr., Leonard Metcalf, H. K. Higgins, Sidney Smith and P. C. Barney, of the Society, and by Mr. Robert B. Davis, member of the American Society of Civil Engineers.

Mr. A. H. French described the foundations of the Longwood avenue bridge, and President Kimball read a short paper on "Foundations for the Elevated Structures of the Boston Elevated Railway."

Adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

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PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., February 6, 1903.—Called to order at 8.30 p.m. by President Henny.

The minutes of the last regular meeting, and of the annual meeting, were read and approved.

The reports of the Secretary and Treasurer were read, approved and ordered filed.

The tellers appointed to open the ballots reported that Mr. Frederick J. H. Rickon, engineer of the Quartermaster's Department of the Army, had been elected to membership. The Secretary was instructed to notify Mr. Rickon of his election.

The following applications for membership were made: Geo. W. Nichols, electrical engineer of Bella Vista, Cal. Proposed by A. Lietz, E. T. Schild and Hermann Kower. Oliver N. Sanford, civil engineer, San Francisco. Proposed by C. E. Grunsky, F. C. Herrmann and H. D. Connick.

The applications, having been approved by the Board of Directors, were ordered prepared for ballot.

Mr. Marsden Manson spoke of the approach of the twentieth anniversary of the founding of the Technical Society, and suggested that a gold medal be struck to commemorate this event, and that this medal be awarded, under certain conditions, to the member whose engineering services had been recognized as eminent in the state. The proposition was simply a suggestion indicating some line of action to which the members of the Society might give their attention and for the discussion of which a time might be set. The President thought the proposition one that should be entertained, but would leave the matter in the hands of the members to be definitely brought before the Society.

Mr. Connick moved that a committee of three be appointed, who, together with the President, represent the Technical Society in the matter of the water and forest irrigation bill, now before the Assembly of the State Legislature at Sacramento, and that this committee there present the views of this Society, as brought out in former discussions, in the matter of this important measure. The motion was carried, and the President subsequently

appointed on this committee Mr. C. E. Grunsky, Prof. Charles D. Marx and Mr. Marsden Manson, who were informed of their appointment by the Secretary.

Mr. Carroll Bennink thereupon addressed the Society on the subject of "The Missions of Southern California," illustrated by water-color sketches, by which he showed the design, the architectural beauties and the method of building these interesting and venerable structures, that appeal to every Californian as revered landmarks of the romantic past of the state.

The President thanked the lecturer in the name of the Society, whereupon the meeting adjourned.

Otto von Geldern, *Secretary.*

Directors' Meeting, San Francisco, Cal., February 6, 1903.—Called to order at 5 p.m. by Director Wallis.

Present, Directors Wallis, Connick, Lietz, Hindes and Von Geldern.

The Secretary read the minutes of the two preceding meetings, which were referred to the regular meeting.

The reports of the Secretary and Treasurer were also read and referred.

The following committees were appointed:

Executive Committee—Geo. H. Wallis, S. G. Hindes and H. D. Connick.

Finance Committee—L. J. Le Conte, Adolf Lietz and Carl Uhlig.

Members on the Board of Managers of the Association of Engineering Societies—D. C. Henny and Otto von Geldern.

Upon motion the salary of the Secretary was approved at the rate heretofore fixed, and the dues remitted.

Also the Treasurer's dues were remitted for services rendered.

Miss M. N. Garretson was appointed collector for the Society and the rate fixed at eight per cent. on dues collected, as heretofore.

The following applications for membership were read and approved: Geo. W. Nichols, electrical engineer, of Bella Vista, Cal. Proposed by A. Lietz, E. T. Schild and Hermann Kower. Oliver N. Sanford, civil engineer, San Francisco. Proposed by C. E. Grunsky, F. C. Herrmann and H. D. Connick.

After discussing methods of obtaining professional papers for the ensuing term, the meeting adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

The annual dinner of the Engineers' Club of St. Louis was held Wednesday evening, December 17, 1902, at the St. Nicholas Hotel, President Kinealy presiding, thirty-two members and ten guests being present. It was the 553d meeting of the Club.

After the dinner President Kinealy called the Club to order and the result of the letter ballot for officers for the year 1903 was announced. The result of the election was as follows: President, J. L. Van Ornum; vice-president, J. A. Ockerson; secretary, H. J. Pfeifer; treasurer, E. E. Wall; librarian, E. B. Fay; directors, W. G. Brenneke and S. H. Freeman, members of Board of Managers, E. R. Fish and F. F. Bausch.

The retiring President made a few remarks appropriate to the occasion in turning over the affairs of the Club to the new President, J. L. Van Ornum, who acted as Toastmaster the rest of the evening.

The toast, "Theory and Practice," was responded to by Professor Kinealy and was followed by the inaugural remarks of President Van Ornum. "The Gas Engine Up to Date" was responded to by Prof. R. H. Fernald and "Our World's Fair" by J. A. Ockerson. All responses were given in a manner and spirit demanded by the occasion and were enthusiastically received. The toasts were interspersed with piano music by Mr. Vieh and songs by Mr. Kessler and members of the Club, all members joining in the choruses.

After the regular program had been concluded the remainder of the evening was taken up with entertaining stories and anecdotes told by the different members who responded when called upon.

This most enjoyable evening was finally concluded by all members joining in singing the song entitled "The Engineer."

E. B. Fay, *Secretary pro tem.*

Following are the minutes of the 554th meeting, held at the Club rooms, 709 Pine street, St. Louis, Wednesday, January 7, 1903, at 8 p.m., President Van Orum in the chair. Present, nineteen members and nine visitors. The minutes of the 552d and 553d meetings were read and approved. The minutes of the 339th and 340th meetings of the Executive Committee were read.

A letter from Mr. J. S. Branne, acknowledging receipt of the fifty-dollar prize and certificate of award for the best paper read before the Club during the season 1900-1901, was read.

The applications for membership of J. L. Campbell, Wm. E. Perrine, Edw. J. Schneider and Jas. K. Broderick were read by the Secretary and referred to the Executive Committee. Messrs. Robt. H. Fernald, Edw. G. Helm, Thos. M. Meston and R. Lincoln Murphy were, on ballot, elected to membership.

There was a discussion on the appointment of a Program Committee, participated in by Messrs. Johnson, Bryan, Layman and Swope. Following this, Mr. Langsdorf moved that the Program Committee be appointed by the President. The motion was seconded, but lost.

It was moved by Mr. Fish, and seconded, that the hour of meeting of the Club be changed from 8 to 8.15 p.m. The motion was carried.

It was moved by Mr. Swope that the Entertainment Committee be also made a Committee on Membership, its duties to consist in putting forth special efforts toward increasing the membership of the Club. This was seconded and carried.

The regular discussion of the evening, on "The Use of Electric Power in Factories," was opened by Mr. Layman. Mr. Layman stated that the efficiency of the best methods of electric drive was 70 per cent., as compared with 20 or 25 per cent. in belt drive. Another advantage claimed was that individual tools could be operated at a great saving in power, and that for night work, one department only of a shop running, it could be supplied with power from some outside source, while in belt drive it would be necessary to run the regular shop engine. Mr. Layman showed a number of diagrams illustrating his paper.

Mr. Cooper, of the Bullock Manufacturing Co., spoke on the increased output per tool, due to the great speed variations possible, enabling all tools to be run at their maximum speed, thus increasing the tool output two or three times over the old method.

Mr. Schwedtman made the point that the great desideratum in factories is not so much motor efficiency as gain in the output per tool. He stated that European practice at present is a combination of mechanical and electrical speed control. European practice also favors alternating current motors.

Mr. Humphrey stated that the relative availability of direct current and alternating current motors depends on the work required. In railroad shops, large machine shops, etc., on account of the variety of service required. such as the running of cranes, lifting of heavy weights, etc., direct current is the best.

The discussion was further participated in by Messrs. Johnson and Cooper, the latter answering a number of questions put to him by the former.

There being no further business, the meeting adjourned.

H. J. Pfeifer, *Secretary.*

Engineers' Club of Minneapolis.

164th Meeting, Minneapolis, Minn., February 16, 1903.—The 164th meeting of the Engineers' Club of Minneapolis consisted of an annual dinner given at the rooms of the Commercial Club at 6.30 p.m. Covers were laid for sixty-five members and guests of the Club. Music was rendered by an orchestra during the progress of the dinner, and toasts were responded to as follows:

Hon. J. C. Haynes, "Brains."

Geo. W. Sublette, "Old War Horses."

Prof. Fred S. Jones, "The College of Engineering."

Andrew Rinker, "Early Days."

Prof. Geo. D. Shepardson, "Electricity in the Future."

Geo. W. Cooley, "Present and Prospective Good Roads."

Prof. H. D. Eddy, of the Engineering College. and Mr. E. T. Abbott, charter member of the Club, also made short addresses.

Mr. Wm. W. Redfield acted as toastmaster in the absence of Mr. W. H. Eustis.

President Avery announced the standing committees for the year 1903, as follows:

Program and Entertainment—L. S. Gillette, F. E. Rice, W. D. Wheeler, F. H. Nutter, E. F. Peabody, Jr., Geo. D. Shepardson, W. I. Gray, W. E. Stoopes, E. M. Grime, Geo. W. Sublette, Chairman.

Membership—Hugo Arnold, J. C. Moore, H. C. Tregillus, W. P. Cowles, A. Graber, Geo. W. Chestnut, K. Oustad, R. D. Thomas, P. Bellin, W. R. Hoag, Chairman.

James B. Gilman, *Secretary.*

Detroit Engineering Society.

70th Regular Meeting, Detroit, Mich., February 27, 1903.—Held in the parlors of the Hotel Ste. Clair.

After the usual round-table dinner at which ten members were present, the meeting was called to order by the President, E. E. Haskell, at 8.10 p.m.

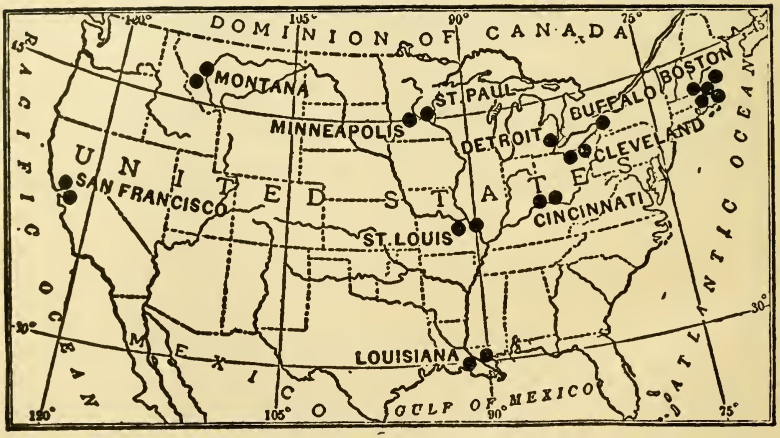
The following names were proposed for membership: Clyde Potts, U. S. Junior Engineer, 33 Campau Building, proposed by Francis C. Shenehon and H. F. Johnson; Fred O. Ray, civil engineer to the Park and Boulevard Committee, proposed by Clarence W. Hubbell and W. E. Hewitt. The following men were elected to resident membership: Theodore Zealand, draftsman with Michigan Central Railroad, proposed by Geo. Parks; James T. Warner, draftsman with Whitehead & Kales, proposed by W. R. Kales; Wellington Roberts, U. S. Lake Survey, proposed by E. E. Haskell; Fred W. Haines, Triumph Electric Company, proposed by Byron E. Parks; John A. Ubsdell, Jr., marine architect with Great Lakes Engineering Company, proposed by F. Mason and W. S. Russel; F. R. Still, American Blower Company, proposed by Geo. A. Mattsson.

Moved by Mr. Geo. Robinson and seconded by Byron E. Parks, that the nomination of Gardner S. Williams to represent the Society upon the Board of Managers of the Association of Engineering Societies for the current year be confirmed. Unanimously carried.

The paper of the evening, entitled "Some Engineering Experiences in a Tannery," was then read by Byron E. Parks, and discussed by Dr. Stephens, N. J. Schorn, C. G. Wrentmore, Francis Shenehon and others.

President Haskell gave notice of the next meeting to be held in the Fellowcraft Club Hall, on April 3d, at which time E. L. Corthell will give an illustrated lecture on "Two Years as Consulting Engineer in the Argentine Republic."

The meeting then adjourned. C. W. Hubbell, *Secretary.*


DOMINION OF CANADA
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UNITED STATES
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MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXX. **MARCH, 1903.** NO. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, MASS., FEBRUARY 18, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 7.50 P.M.

President George A. Kimball in the chair; eighty-two members and visitors present.

The record of the last meeting was read and approved.

The Treasurer called attention to the condition of the permanent and the current funds of the Society, and, on motion, it was voted to transfer the sum of $500 from the current fund to the permanent fund.

On motion of Mr. Worcester, the following vote was passed:

Voted: That a committee of three be appointed by the President to consider what, if any, changes should be made in the Boston Building Law, to make it conform more closely to the requirements of good engineering practice of the present day;

That this committee be requested to report to the Society at its regular meeting in September, 1903, what, if any, amendments to the Building Law should be made, and what steps can be taken by the Society with a view to procuring the adoption of such amendments;

That the Secretary be instructed to inform the Boston Society of Architects of the appointment of this committee and to invite the said Society to co-operate with the Boston Society of Civil Engineers in this object.

The President appointed as members of the committee Messrs. J. R. Worcester, J. E. Cheney and H. A. Phillips.

Mr. Leonard Metcalf, chairman of committee chosen at the last meeting to nominate officers, brought to the attention of the Society the difficulty experienced by nominating committees in securing the consent of three members to stand as candidates for each office. He submitted for the committee a proposed amendment to By-law 5, but on

objection being raised that the committee had only authority under the By-laws to present nominations to the Secretary, he proposed on his own behalf the following amendment: "Amend the first paragraph of By-law 5, so as to read, 'Officers shall be elected as follows: At the regular meeting in January, the Society shall choose a nominating committee of five, who shall submit to the Secretary within three weeks the names of one, two or three candidates for each office to be balloted for.' "

After a short discussion by Messrs. Howland, French, Manley and Rice and a ruling by the chair that the By-law had been duly presented in writing, on motion of Mr. Coffin, it was voted to refer the proposed amendment to a committee of five for consideration.

The President has appointed as that committee Messrs. F. C. Coffin, Leonard Metcalf, Henry Manley, Otis F. Clapp and C. W. Sherman.

Mr. R. A. Hale, for himself and Mr. A. D. Marble, a committee appointed to prepare a memoir of Moses W. Oliver, read its report.

On motion of Mr. Holmes, the thanks of the Society were voted to C. L. Berger & Sons for courtesies extended to members of the Society this afternoon on the occasion of the visit to the works of that company.

Mr. Manley called attention to the date selected for the Twenty-first Annual Dinner, March 3, 1903, and that notices would be sent to all members of the Society shortly.

Mr. Robert B. Davis read a paper entitled "Foundation for Coal Pocket at Lincoln Wharf for the Boston Elevated Railway Company." The paper was illustrated by plans and photographs.

Mr. Clarence T. Fernald read a short paper on "The Failure of a Sea Wall and its Reconstruction." The paper was illustrated by numerous drawings and photographs.

The Secretary read a paper prepared by Mr. George B. Francis on "Foundations in General and the Safe Loads for Different Classes of Earth."

The discussion on "Foundations" begun at the last meeting was continued, Messrs. Hodgdon, F. P. Stearns, Barney, Henry Manley, E. W. Howe, R. A. Hale, H. S. Adams, Wason, Hastings and Wm. Parker participating.

Mr. A. S. R. MacCurdy gave an account of the concrete sheeting used in connection with the subway work in State street, and Mr. F. W. Hodgdon spoke of the "Action of Sea-worms on the Foundations in Boston Harbor."

Adjourned. S. E. Tinkham, *Secretary.*

TWENTY-FIRST ANNUAL DINNER.

The twenty-first annual dinner of the Boston Society of Civil Engineers was held at the Hotel Vendome, Boston, Tuesday evening, March 3, 1903, and was attended by 146 members and guests. An informal reception was held by the President at half-past five and the dinner was served at half-past six o'clock.

President George A. Kimball presided, and, in opening the post-prandial exercises, welcomed the members and their guests, speaking substantially as follows:

"We meet again at our twenty-first annual dinner, to renew our friendship to each other and to welcome our guests.

"Our Society was founded July 3, 1848, nearly fifty-five years ago. It was incorporated by a special act of the Legislature in 1851, the act having been signed by Gov. George S. Boutwell, who is now the oldest living Ex-Governor of this Commonwealth.

"The Society has prospered during the past year, the membership has slightly increased, and we now have a total of 512 members. Our members and others have contributed liberally to our instruction by presenting a large number of valuable papers, which have been followed by interesting discussions. We have been furnished with facilities for examining the work in progress on a large number of important public improvements.

"Our financial condition is satisfactory, as we shall pay all our current bills and close the year with a small surplus. The permanent fund, which has been accumulating for several years, now amounts to about $15,000, and with its aid it is probable that in a few years we shall be able to obtain a home of our own.

"To our guests we extend a cordial welcome. We thank you for your presence here this evening. We feel honored in having with us gentlemen who are engaged in making our State laws and enforcing them.

"To those who have contributed to our instruction during the past year, by presenting papers and discussions and by furnishing us means for examining interesting work in progress, those who have shown the best methods of conducting the transportation of passengers in cities, and others who have opened their factories and machine shops for our inspection, we return this evening our cordial thanks for their many courtesies.

"To the officers and instructors of our technical institutions, who are furnishing to the engineering profession each year young men well trained for their duties and constituting a valuable addition to our engineering departments, the Boston Society of Civil Engineers extends the assurance that it fully appreciates the good work they have in hand and congratulates them on the material progress they have made during the last few years.

"I wish to thank the officers and representatives of the kindred engineering societies,—many of whom have made personal sacrifices to be present with us this evening,—for their interest in this meeting and in our Society. I think it is important that there should be a closer fellowship between the several engineering societies, and a cordial co-operation of the civil engineer with the mechanical, the electrical and the mining engineer, and the many others who are specialists in their particular lines. This co-operation, in my opinion, is very important in order to secure the best results, and is absolutely necessary in these days of large enterprises. For example, the elevated railroad, which was recently completed in this city, was the result of the work of civil engineers, electrical engineers, mechanical engineers, signal engineers, gas engineers, architects, chemists and the operating department, all working to the same end.

"We cannot successfully work out the great problems which confront us to-day unless we make use of the knowledge possessed by the experts in the several branches of engineering; but if we all work together, each in full sympathy with the others, we shall successfully follow our vocation, which consists in directing the 'great sources of power in nature to the use and convenience of man.'

"Among the engineers who were instrumental in starting our Society in 1848, was George A. Parker, whom I well remember meeting at the time when I occupied the position of chairman on a railroad survey. Mr. Parker was a man of tremendous energy and nerve, an able engineer, and, as I look back over his life, I should say that he left at least three monuments of his skill, viz, the bridge over the Connecticut River at Bellows Falls, the bridge over the Susquehanna River on the Philadelphia and Baltimore Railroad, and the beautiful estate in Lancaster which he transformed from a rough area to a beautiful park, where he made his home, and which is now occupied by his children. We are honored in having with us this evening one of his sons, Mr. Herbert Parker, the Attorney-General of Massachusetts, whom I now present to you."

Attorney-General Parker paid a tribute to the monuments of engineers, and said that he looked upon the achievements of the profession as a mark of the progress of human intelligence and genius. He said, in part, "When I see, in the central part of the State where I live, hills taken away, valleys filled up, rivers diverted from their courses, and, seemingly from the bowels of the earth, an immense masonry wall rise skyward, and am told that some day a vast inland lake will be confined behind it, I ask myself what monument can a lawyer leave behind that will compare with this. People fear that this large dam, impounding the water, threatens the lives of the dwellers in the valley night and day; but the issue has been tried, and the valley below the dam is found to be as safe after as it was before. But lawyers have had a hand in the work. There were cases of land damages to settle, and I pity my successors in office who will wrestle with the cases of 'eminent domain' of the future; for the value of land has now ceased to be expressed by mutual agreement of a sharp buyer and an equally sharp seller. It is more apt to be rated by the engineers who are to work upon it. Think of the tribulations of my successor when such a case comes up. From one point of view the land is looked upon as so much gravel, while the gravel can be made to represent a gold mine in the future when it will be needed for grading a railroad which your contemporaries will eventually run through the district. Our legal profession has its monuments, and they are as lasting as time itself. They are as corporeal as yours; but, long after your steel bridges and stone work are gone, there will still be a law in the land."

The President next introduced Mr. James M. Dodge, President of the American Society of Mechanical Engineers. Mr. Dodge, after reviewing the history of the guilds which all trades once had, pointed out the importance of the trades school to young men, and the need of such schools in the present condition of industry. He said that they should be encouraged and the intelligence of the workingman thereby improved. All professions should employ the best of skilled labor.

The President, in introducing the next speaker, said that engineers are always interested in the work of the Legislature. They watch it with great care from year to year, because the Legislature gives the first notice of great public improvements which are contemplated. The President then introduced Mr. Robert Luce, of Somerville, a member of the present Legislature.

Mr. Luce spoke of the increased co-operation among men, the large public works which modern Legislatures undertake for the good of the public and the reliance which the Legislature places on the technical advice

of the engineering associations. He felt that learned bodies keep Massachusetts a center of intelligence and skill, and set the standards of work high and keep them high.

The next speaker was Mr. Charles F. Scott, of Pittsburg, President of the American Institute of Electrical Engineers, who indorsed the idea of co-operation and said that its influence would be shown on the members of the societies and the community. He said that the days of narrow specialism were past, and that the modern idea of mutual intercourse, evidenced in the formation of local societies, would enable engineers to better undertake the problems of progress. He suggested the establishment of engineering buildings in large cities, where, by a co-operation of societies, men of various professions could be benefited by coming together.

Prof. George F. Swain, a Director of the American Society of Civil Engineers, responded for that Society and mentioned its great influence and prestige. He said the Society should include all engineers who are competent to join, and especially urged all young men to become members.

The other speakers were Prof. John H. Kinealy, a former President of the Engineers' Club of St. Louis, and Capt. William E. McKay, President of the New England Association of Gas Engineers.

The guests of the Society, in addition to the speakers already mentioned, were General W. A. Bancroft, the President of the Boston Elevated Railway Company; Mr. H. P. Eddy, Superintendent of Sewers of Worcester; Robert B. Davis, C.E., and Mr. Frank C. Stowell, of the Boston Elevated Railway Company.

Music was furnished by members of the Apollo Quartette of Boston.

Boston, March 18, 1903.—The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 P.M., President George A. Kimball in the chair; seventy-six members and visitors present.

The record of the last meeting was read and approved.

The Secretary read a letter from Mr. Leonard Metcalf requesting that a letter received from Mr. T. Howard Barnes since last meeting should be read to the Society. The letter was then read and by a vote was referred to the Committee on By-laws.

The following were elected members of the Society: Messrs. Percy C. Barney, Charles R. Gow, David A. Hartwell, Harry S. R. MacCurdy, Lewis F. Patstone and Dean C. Warren.

The Secretary read the annual report of the Board of Government, which was accepted and ordered to be placed on file.

The Secretary also read his annual report, which was accepted and ordered to be placed on file.

The Treasurer read his annual report, which was also accepted and ordered to be placed on file.

The report of the Committee on Excursions was read, accepted and ordered to be placed on file.

The Librarian presented and read the annual report of the Committee on the Library, which was accepted and ordered to be placed on file.

Mr. Howe, in the absence of the Chairman of the Committee on Quarters, made a verbal report, which was accepted.

Mr. Howe also presented the report of the Committee on Advertisements, which was accepted and ordered to be placed on file.

Mr. Coffin, for the Committee on By-laws, made a verbal report of progress, and, on motion of Mr. Hodgdon, it was voted to continue the committee as at present constituted.

On motion of the Secretary, the recommendation of the Board of Government that the practice of buying standard engineering books be continued was adopted.

Mr. McKibben then offered the following vote, which was adopted:

Voted: That the Board of Government be authorized to negotiate with the New England Association of Gas Engineers in the matter of the use of the rooms and library of the Society by members of that Association, and that the President and Treasurer be authorized to sign such agreements as in the judgment of the Board it is desirable to execute.

On motion of Mr. F. L. Fuller, it was voted to refer to the Board of Government, with full power, the question of appointing the several special committees of the Society and the selection of the members thereof.

On motion of Mr. Sherman, it was voted to continue the Committee on Boston Building Laws as appointed at the last meeting.

On motion of Mr. Higgins, it was voted to appoint a committee of three to consider the matter of a badge for the Society and to submit a design for the same. The President has appointed as that Committee Messrs. Isaac Rich, A. E. Burton and R. A. Hale.

On motion of Mr. Brooks, the thanks of the Society were voted to Mr. Frank C. Stowell for the interesting talk given the Society at the informal meeting of February 25, 1903.

On motion of Mr. Rice, the thanks of the Society were voted to Mr. Everett Morss, of the Simplex Electrical Company, for courtesies extended this afternoon during the visit to the works of that company.

Mr. A. W. Parker read the paper of the evening entitled, "Early and Curious Types of the Cantilever Bridge in New England," which was illustrated by lantern slides. The Secretary read a short discussion of the paper by Mr. J. R. Worcester, and the discussion was continued by Messrs. Rice, Hartwell, Dean and others.

On motion of Mr. Brooks, the thanks of the Society were voted to Mr. Parker for his interesting paper.

President George A. Kimball then delivered a short address, speaking substantially as follows:

ADDRESS OF PRESIDENT GEORGE A. KIMBALL.

In closing our work for the year, I wish to thank you for the great honor which you conferred upon me a year ago in electing me your President. It has been a pleasure to serve you in this capacity, and I shall always cherish this mark of respect which I have received at your hands.

I also wish to thank the officers and members of the Society for their kind co-operation during the year. Much credit is due to those who have prepared and read papers before the Society at the regular meetings, and to those who have taken part in the discussions. Our thanks are also due to those who have given us verbal descriptions of their work and methods at

the informal meetings, and to others who have furnished us with opportunities to examine many interesting engineering works during construction.

Our Society is now strong and influential. We have 509 members. Our financial condition is good, our annual dues are sufficient to meet our current expenditures and we have nearly $15,000 accumulated as a permanent fund. It is probable that this will increase at the rate of $1000 per year for the next few years, and it is hoped that in the near future we may have a building of our own.

Our library contains nearly 5000 volumes of valuable engineering literature; it is located in a central and convenient place in the city, is well arranged and is a great convenience to our members.

The work of the Society in the past has been excellent; valuable papers, which are a material addition to our personal libraries, have been contributed and published. The influence of the Society in the community is good and is constantly increasing. It has the respect and confidence of public officials and others with whom its members associate in business, and it is also repected and looked up to by engineers all over the country, both because it is the oldest engineers' society in this country and one of the largest of the local societies, and because a marked advancement in the profession itself has been made through the efforts of its members.

The question which I wish to ask of the members of this Society to-night, and which I wish you would consider, is this: Is the Boston Society of Civil Engineers—considering its present strength, wealth and influence—making itself as useful in the community as it should? I think not. We are too narrow; we confine ourselves too closely to a single branch of civil engineering. This narrow policy was well enough a few years ago when nearly all the engineers in this vicinity were engaged in municipal work consisting mostly of small undertakings, but to-day we are dealing with large and varied problems. The design and construction of all our great improvements require trained men from all branches of the engineering profession.

I am convinced that it is the mission of our Society to bring together under one roof the men who are engaged in the several branches of our profession, arrange for the presentation, discussion and publication of papers in each of the several branches of engineering, provide for informal meetings where members may engage in the investigation and free discussion of the many important details that now enter into all our designs, furnish opportunities for social intercourse among members where they may seek and obtain advice in regard to the particular work which they may have in hand and cheer and help each other to surmount the difficulties which must constantly be overcome in connection with the exacting duties of our profession. The civil engineer needs the help of engineers who are trained in other branches of engineering work; he cannot make a great success without them; they also need him, and through our Society they can be of great assistance to each other.

My friend, the late Albert F. Noyes, who was your President in 1896, called your attention to this matter, and I quote a few extracts from his address:

"The Society has already become so large that there are sufficient numbers of representatives of almost every branch of engineering to form a nucleus for the organization of a separate society representing the interests of each branch. Already have the interests in water-works and highway con-

struction and maintenance become so great that organizations have been formed which have included in their membership a large number of members of this Society."

. . . .

"There are, however, other branches of engineering, namely, the mechanical, the marine, the railroad, the municipal, the electrical and the sanitary engineer, whose membership in the Society have become so large as to lead some to seriously consider the organization of societies or clubs dealing with questions of special interest to their branch of the profession. There does not appear to be the large field from which to draw any considerable number of persons to such societies or clubs if formed, who would not be eligible for membership to this Society; hence the organization of such societies can be considered, if withdrawing attendance and interests in this Society, as a means of decreasing its usefulness.

"The question now before us, as the membership increases, and its numbers become so great as to make the body in some respects unwieldy, is how to get the greatest possible good to all working in the special lines which the profession is bound to divide itself into. As it is necessary that each specialist should be in touch with the other's works, it is, I believe, by the work of this Society, that these results can be accomplished."

I would recommend that the Society take up the several branches of engineering as fast as the needs of our community require. From an investigation of the conditions now prevailing, I believe it should immediately organize branches for the study of mechanical engineering and sanitary engineering to meet needs already existing. There are no local societies in this vicinity devoted to these subjects, and I am convinced that there are many young men who would join us if these topics were to be treated by our Society.

I would suggest that each of the several branches be placed in charge of a Vice-President, who shall himself be an expert in his particular branch, and under the direction of the Board of Government shall have charge of all matters relating to that branch of the Society.

At the conclusion of his address the President called for the report of the tellers of election, Messrs. A. L. Plimpton and Herbert R. Stearns. In accordance with their report the following officers were declared elected:

President—Ira N. Hollis.

Vice-President (for two years)—Dwight Porter.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Frank P. McKibben.

Director (for two years)—Joseph R. Worcester.

Before declaring the meeting adjourned, the President requested Messrs. F. O. Whitney and H. B. Wood to conduct the President-elect to the chair, where he was greeted by the retiring President and presented to the Society. Professor Hollis thanked the members for the honor of the election to the Presidency of the Society and promised his best efforts for the interest of the Society during the coming year.

Adjourned. S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1902-1903.

Boston, March 18, 1903.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the Constitution the Board of Government submits its report for the year ending March 18, 1903.

At the last annual meeting the total membership of the Society was 507, of which 499 were members, 2 honorary members and 6 associates.

During the past year we have lost 14 members, 9 by resignation, 3 by forfeiture of membership for non-payment of dues and 2 have died.

There have been added to the Society during the year 16 members, 15 elected by vote of the Society and 1 temporary member has been admitted by the Board of Government. Our present membership consists of 2 honorary members, 5 associates and 502 members, a total of 509.

The record of deaths during the year is Frank E. Fuller, died August 1, 1902; Henry Mitchell, died December 1, 1902.

Eleven meetings have been held during the year, nine regular and two special, and the twenty-first annual dinner was given at the Hotel Vendome on March 3, 1903. The average attendance at the regular and special meetings was 86. The largest attendance was 158 and the smallest 28. The attendance at the annual dinner was 146.

The following papers have been read at the several meetings:

March 19, 1902.—Prof. L. P. Kinnicutt, "The Present Status of the Sewage Purification Problem in England." (Illustrated.) Discussion.

Address of President L. B. Bidwell.

April 16, 1902.—Mr. Desmond FitzGerald, "Talk on Chicago Drainage Canal." (Illustrated.)

May 14, 1902.—(Special in place of regular May meeting.)

Mr. George B. Francis, "Light Mountain Railways."

Mr. George B. Francis, "Street Railway System of Providence and Vicinity."

Mr. Arthur L. Plimpton.—"Street Railway Track Construction in City Streets."

Mr. Henry Manley, "Relation of Street Railway Tracks to the Paving of City Streets."

Mr. Gilbert Hodges, "Track and Overhead System for an Interurban Electric Railway."

Mr. Harold Parker, "Street Railways and State Highways."

June 18, 1902, Mr. F. W. Hodgdon, "Surveys for a Canal from Taunton River to Boston Harbor."

September 17, 1902.—Mr. Howard A. Carson, "Tunnel Construction Under Water." Discussions of Mr. John F. O'Rourke, C.E., of New York, and Mr. John Ericson, City Engineer of Chicago. (Illustrated.)

October 22, 1902.—Mr. Edmund K. Turner, "The Abolition of Grade Crossings in Massachusetts." Discussion.

November 19, 1902.—Mr. X. Henry Goodnough, "A Description of Sewage Disposal Systems in Massachusetts." (Illustrated.)

Mr. F. Herbert Snow, "Adaptability of Massachusetts Methods to Sewage Disposal Problem in Other States." Discussion by Mr. Harrison P. Eddy, Superintendent of Sewers, Worcester, Mass., and members of the Society.

December 17, 1902.—Mr. Elmer L. Corthell on "Argentina, Past, Present and Future." (Illustrated.)

January 14, 1903 (special).—Mr. Frank S. Hart, "A Comparison of Three Methods of Estimating Quantities of Soil Stripping from Water Supply Reservoirs."

Mr. Charles A. Bowman, "Method used in Estimating Soil Stripping on the Wachusett Reservoir." Discussion.

January 28, 1903.—Mr. J. R. Worcester on "Boston Foundations." Discussion.

Mr. A. H. French, "Foundations of Longwood Avenue Bridge."

President George A. Kimball, "Foundations for the Elevated Structures of the Boston Elevated Railway." Memoir of F. E. Fuller.

February 18, 1903.—Mr. Robert B. Davis, "Foundations for Coal Pocket at Lincoln Wharf."

Mr. Clarence T. Fernald, "Failure of a Sea Wall and its Reconstruction." Continuation of discussion on foundations with papers by G. B. Francis, R. A. Hale, L. M. Hastings, H. S. Adams, William Parker and others.

Mr. H. S. R. MacCurdy, "Concrete Sheeting."

Mr. F. W. Hodgdon, "Action of Sea Worms on the Foundations in Boston Harbor." Memoir of M. W. Oliver.

Seven informal meetings have been held in the Society's library during the past year. The subjects discussed at these meetings have been as follows:

March 26, 1902.—Mr. Henry S. Adams, "Placer Mining."

April 2, 1902.—Mr. Edward D. Sabine, "Pneumatic Tube for Parcel Delivery in Boston."

January 7, 1903.—William E. McClintock, "State Road Construction."

February 4, 1903.—H. F. Bryant, "Reconstruction of Foundations under Hotel Wollaton, Brookline."

February 11, 1903.—Lewis M. Hastings, "Separate Sewer Construction in Cambridge."

February 25, 1903.—Frank C. Stowell, Roadmaster, Elevated division, Boston Elevated Railway, "Electric Pneumatic Block System used in Operating the Elevated Trains."

March 11, 1903.—Percy C. Barney, "Work at Charlestown Navy Yard."

During the year under the authority of a vote of the Society there has been executed with the Tremont Temple Baptist Church a lease of our present quarters for a term of three years, with the privilege of renewal for three years. A lease has also been executed with the New England Water Works Association for three years. The Hersey Manufacturing Company still occupy the room as tenant at will.

An inquiry has been made by the directors of the New England Association of Gas Engineers with regard to the use of our rooms by its members, and for an opportunity to place there the few books which the Association owns. The Board has replied that it viewed with favor any movement tending towards a common headquarters of the several engineering societies located in Boston. While no official notification has been received of any action taken by the Association of Gas Engineers, the Board understands that a vote has been passed by authority of which application will be made to this Society for the use of our rooms by members of that Association.

The Board of Government believes that the practice begun five years ago of buying standard engineering books for the library has proved beneficial and would recommend that it be continued for the coming year.

Respectfully submitted for the Board of Government.

George A. Kimball, *President.*

Abstract of the Treasurer's and the Secretary's Reports for the Year 1902-1903.

CURRENT FUND.

Receipts:		
Dues from new members	$66.00	
Dues for year 1894-1895	7.00	
Dues for year 1902-1903	3,412.00	
Dues for year 1903-1904	59.00	
Sales of Journals and from library fines	11.77	
Rent of rooms	900.00	
Advertisements in Journal	140.00	
Interest on deposits	14.14	
Balance on hand, March 20, 1902	593.70	
		$5,203.61
Expenditures:		
Rent	$1,650.60	
Association of Engineering Societies	1,015.95	
Transfer to Permanent Fund	500.00	
Printing, postage and stationery	423.95	
Secretary's salary	400.00	
Library supplies and clerical assistance	137.48	
Incidentals	118.34	
Reporting meetings	96.50	
Binding	79.40	
Periodicals	61.75	
Annual dinner	65.50	
Stereopticon at meetings	50.00	
Lighting rooms	17.41	
Books	10.30	
Insurance	14.36	
Commission on advertisements	42.00	
		4,683.54
Balance on hand, March 18, 1903		$520.07

PERMANENT FUND.

Receipts:		
Transfer from Current Fund	$500.00	
Savings banks, interest on deposits	234.35	
Workingmen's Co-operative Bank (shares retired)	199.58	
Merchants' Co-operative Bank (shares retired)	182.53	
Subscription to Building Fund	100.00	
Interest on bond	36.00	
Fifteen entrance fees	150.00	
Balance on hand, March 20, 1902	4.50	
		$1,406.96
Expenditures:		
Dues on shares Workingmen's Co-operative Bank	$304.04	
Dues on shares Merchants' Co-operative Bank	304.00	
Dues on shares Volunteer Co-operative Bank	300.00	
Deposit in Provident Institution for Savings	43.03	
Deposit in Boston Five-cents Savings Bank	40.15	
Deposit in Eliot Five-cents Savings Bank	38.49	
Deposit in Warren Institution for Savings	37.99	
Deposit in Institution for Savings in Roxbury	37.52	
Deposit in Franklin Savings Bank	37.17	
		1,142.39
Balance on hand, March 18, 1903		$264.57

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 18, 1903.

25 shares Volunteer Co-operative Bank	$2,824.25
25 shares Workingmen's Co-operative Bank	2,508.27
25 shares Merchants' Co-operative Bank	1,926.42
Deposited in Provident Institution for Savings	1,262.28
Deposited in Boston Five-cents Savings Bank	1,177.28
Deposited in Eliot Five-cents Savings Bank	1,129.07
Deposited in Warren Institution for Savings	1,114.60
Deposited in Institution for Savings in Roxbury	1,101.42
Deposited in Franklin Savings Bank	1,090.58
One Republican Valley Railroad bond (par value)	600.00
Cash on deposit in Old Colony Trust Co	264.57
	$14,998.74
Amount as per last annual report	13,650.74
Increase during the year	$1,348.00

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$14,998.74
Current Fund	520.07
	$15,518.81
Amount as per last annual report	14,244.44
Total increase during the year	$1,274.37

Report of Committee on Excursions.

Boston, March 18, 1903.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions submits herewith its annual report.

Thirteen excursions have been made during the year, as follows:

April 16, 1902.—To the wharves, sheds and warehouse of the Boston and Albany Railroad Company, at East Boston. Attendance, 25.

May 14, 1902.—To the car house, machine shop and power station of the Union Railway Company, at Providence, R. I. Attendance, 60.

June 18, 1902.—To the Metropolitan High Level Sewer and the Forbes Hill Reservoir, at Quincy. Attendance, 20.

July 23, 1902.—To the concrete sea wall, built by the Harbor and Land Commission, at Hull, and to the Metropolitan Park Reservation, at Nantasket Beach. Attendance, 45.

September 17, 1902.—To the Stony Brook Conduit, at Jamaica Plain. Attendance, 16.

September 20, 1902.—To the launching of the cruiser "Des Moines," at the Fore River Shipyard, and to the Metropolitan Sewage Outfall at Nut Island, Quincy. Attendance, 170.

October 15, 1902.—To the Natick Reservoir. Attendance, 30.

October 22, 1902.—To the Weston Aqueduct. Attendance, 25.

November 19, 1902.—To the Wachusett Dam, at Clinton. Attendance, 20.

December 19, 1902.—To the Charlestown Navy Yard. Attendance, 25.

January 28, 1903.—To the American Waltham Watch Company's factory, at Waltham. Attendance, 80.

February 18, 1903.—To the instrument factory of C. L. Berger & Sons. Attendance, 20.

March 18, 1903.—To the factories of the Simplex Electrical Company, Eastern Expanded Metal Company, and Morss & White, Cambridge. Attendance, 25.

Total attendance, 560; average attendance, 43.

Twenty-four pages of the "Bulletin of Engineering Work" have been published during the year. The committee wishes to thank those who have aided in this work.

There is a cash balance of $21.18 in the hands of the Treasurer.

Respectfully submitted,

J. A. Holmes, *Chairman,*
D. C. Webb, *Sec'y and Treas.,*
H. D. Woods,
H. K. Higgins,
D. L. Hubbard.

Report of the Library Committee.

Boston, March 18, 1903.

To the Members of the Boston Society of Civil Engineers:

The Committee on the Library makes the following report for the year 1902-1903:

During the past year 237 bound volumes have been added to the library, 4 of these have been purchased by the Society, 50 are gifts, 148 are public reports and miscellaneous volumes received already bound from their original sources, and 35 have been bound by this Society. The last accession number is 5000, but this does not represent the actual number of books in the library, for in some past years pamphlets were given an accession number. A new periodical case, in which are kept the current numbers of the smaller publications, has been added during the year, and has been found very useful.

The principal gifts are those of Mr. R. S. Hale and Mr. C. W. Folsom.

Within a year's time more shelf room will be needed. This can be provided by the addition of a suitable bookcase or by enlarging the present quarters. Some room can be gained by disposing of duplicate books, pamphlets and periodicals, and this should be done at once. Many complete sets of pamphlets now loose on the shelves or in pamphlet cases should be bound, and an effort should be made to complete the files of many of the municipal and state reports and periodicals. Much of this work has been done during the past year, but there is still a great deal to do.

The committee wishes to recommend that the practice of buying standard engineering books for the library be continued for the coming year.

Respectfully submitted,

Frank P. McKibben,
Henry F. Bryant,
Frank H. Carter,
Frederic I. Winslow,
Committee on the Library.

Detroit Engineering Society.

70TH REGULAR MEETING, DETROIT, MICH., FEBRUARY 27, 1903.—Held in the parlors of the Hotel Ste. Clair.

After the usual round-table dinner at which ten members were present, the meeting was called to order by the President, E. E. Haskell, at 8.10 P.M.

The following names were proposed for membership: Clyde Potts, U. S. Junior Engineer, 33 Campau Building, proposed by Francis C. Shenehon and H. F. Johnson; Fred O. Ray, civil engineer to the Park and Boulevard Committee, proposed by Clarence W. Hubbell and W. E. Hewitt. The following men were elected to resident membership: Theodore Zealand, draftsman with Michigan Central Railroad, proposed by Geo. Parks; James T. Warner, draftsman with Whitehead & Kales, proposed by W. R. Kales; Wellington Roberts, U. S. Lake Survey, proposed by E. E. Haskell; Fred W. Haines, Triumph Electric Company, proposed by Byron E. Parks; John A. Ubsdell, Jr., marine architect with Great Lakes Engineering Company, proposed by F. Mason and W. S. Russel; F. R. Still, American Blower Company, proposed by Geo. Mattsson.

Moved by Mr. Geo. Robinson and seconded by Byron E. Parks, that the nomination of Gardner S. Williams to represent the Society upon the Board of Managers of the Association of Engineering Societies for the current year be confirmed. Unanimously carried.

The paper of the evening, entitled "Some Engineering Experiences in a Tannery," was then read by Byron E. Parks, and discussed by Dr. F. T. F. Stephenson, N. J. Schorn, C. G. Wrentmore, Francis Shenehon and others.

President Haskell gave notice of the next meeting to be held in the Fellowcraft Club Hall, on April 3d, at which time E. L. Corthell will give an illustrated lecture on "Two Years as Consulting Engineer in the Argentine Republic."

The meeting then adjourned. C. W. HUBBELL, *Secretary.*

Engineers' Club of Minneapolis.

165TH MEETING, MINNEAPOLIS, MINN., MARCH 16, 1903.—Called to order by President Avery, in the County Commissioners' room, Court House. About forty members and visitors were present.

The following new names were proposed for membership: Floyd E. Cates, W. T. Conant, Henry Hoke, Leslie E. Benson, H. W. Bennicke, John Gemlo, J. R. W. Ambrose, Frank D. Chase.

A. H. Holt was elected to membership.

Mr. Redfield reported for Mr. Carroll, Librarian, that a library suitable for the purpose could be obtained for less than $40.

Mr. Carroll also requested that $15 be set aside for binding magazines now on hand. No action was taken by the Club.

The special committee which had been appointed to investigate the advisability of making an exhibit at the Louisiana Purchase Exhibition at St. Louis, handed in a report recommending that such an exhibit be made. No action was taken.

The program of the evening was then taken up. Mr. C. A. P. Turner read a paper on "County Bridges." He outlined the loadings which should be used in the design of country highway work, and the type of truss to be

selected for various length spans. He also pointed out the defects in the ordinary highway bridges as they are now built, and called attention to some of the faults in the common method of letting highway work, comparing it unfavorably with the method in vogue with the railroads. A discussion of the paper followed by Messrs. Fanning, Hoag, Gilman and Turner.

Prof. W. R. Hoag then read a paper on "The Work of the State Drainage Commission." After giving a short account of the early attempts at ditching as made by J. J. Hill and the Red River counties, Professor Hoag outlined the systematic and effective work done by the State. He also gave an account of some of the difficulties which were to be met with and overcome, in order to keep the ditches in repair. About fifty slides were shown.

Mr. Fanning followed with some reminiscences of his own work in connection with the ditches.

A motion was made and carried that both papers be published in the JOURNAL.

The meeting then adjourned. J. B. GILMAN, *Secretary.*

Engineers' Society of Western New York.

REGULAR MEETING, BUFFALO, N. Y., FEBRUARY 3, 1903.—Held at their rooms, 533 Ellicott Square, Buffalo, N. Y., Tuesday, February 3, 1903.

The meeting was called to order by Vice-President Tutton with the following members present: Fell, Bassett, Golden, Buttolph, Boardman, March, Kielland, Haven, Roberts, Norton, C. M. Morse, Murphy, Früaff and Eighmy.

The minutes of the last meeting were read and approved.

The application of Mr. Reeves Smith for admission to the Society as member was read. This having been approved by the Executive Board was approved by the Society and ordered to letter ballot.

Mr. William H. Lawrence and Mr. Henry P. Burgard were reported elected to membership of the Society as associates.

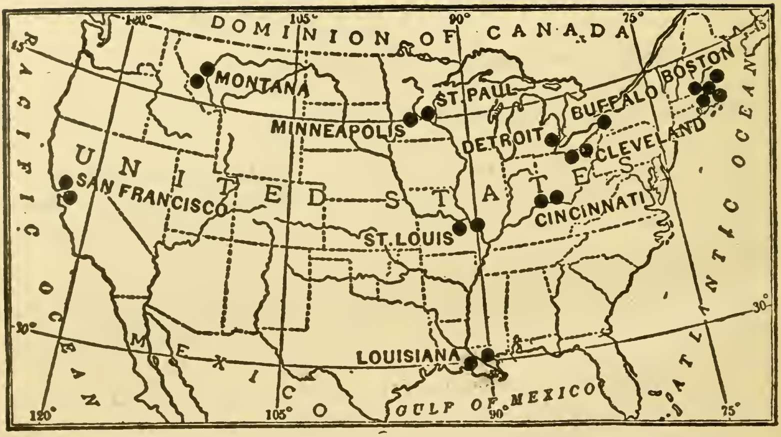
The proposed amendment to the constitution to allow all classes of membership the right to vote and hold office was seconded by two-thirds of the members present.

Mr. George H. Norton presented a paper on the "Hydraulic Questions of the proposed Buffalo River Improvement."

Messrs. Tutton and Kielland made some remarks on the subject. A vote of thanks was extended to Mr. Norton for the paper.

Adjourned at 10.30 P.M.

LEE W. EIGHMY, *Secretary.*


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BOSTON
BUFFALO
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°

Association of Engineering Societies.

Vol. XXX. APRIL, 1903. No. 4.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., March 6, 1903.—Called to order at 8.30 p.m., by Past-President Geo. W. Dickie.

The minutes of the last regular meeting were read and approved.

The following applicants were elected to membership: Oliver N. Sanford, of San Francisco, and Geo. W. Nichols, of Bella Vista.

The following applications were read and, having been acted upon by the Board of Directors, they were ordered to go to ballot:

For Members.—R. W. Myers, electrical expert, U. S. Engineers Department. Proposed by A. Ballantyne, Thomas Smith and Adolf Lietz; Augustus Kempkey, Jr., civil engineer, of Oakland, Cal. Proposed by Hermann Kower, L. J. Le Conte and E. T. Schild; J. J. Welsh, architect, of San Francisco. Proposed by A. Ballantyne, Thomas Smith and Hermann Barth.

Mr. C. L. P. Marais appeared before the Society on behalf of Mr. Emile Villet, civil engineer, and addressed the members on the subject of "Reinforced Concrete Work as Applied to Pile and Wharf Building," describing Mr. Villet's method of constructing armored concrete piles that may be driven with a hammer, and illustrating the designs of complete wharf structures, made of reinforced concrete, as built by Mr. Villet on the Black Sea.

This interesting subject was discussed by many of the members present, but owing to the lack of time, it was agreed that it be again brought up at the next regular meeting of April, and that Mr. Marais elaborate the paper by additional data, so as to draw out many more of the details that could not be touched upon during the limited time at disposal.

Mr. S. Giletti then submitted a paper on the Giletti system of concrete and iron construction in tall buildings, which was read by Mr. J. J. Welsh, the discussion of which had to be postponed for want of time.

Mr. Charles List thereupon read a paper concerning certain personal experiences in the building of an iron wharf at Ocos on the coast of Guatemala, relating the manner of setting iron pipes for piles on an exposed coast, and the method of repairing injuries wrought during the recent earthquakes. He suggested the forcing of cement grout into and through the walls of the perforated piles below the sand line, and in this manner sur-

rounding the pile with a coating of actual concrete adhering to its skin. From his past experience he had been led to believe that this might be resorted to with success in clean, sandy sea bottom.

All these papers were illustrated fully by drawings, diagrams and sketches.

After ordering all discussion postponed to the meeting of April, this meeting adjourned.

Otto von Geldern, *Secretary.*

Regular Meeting, San Francisco, Cal., April 3, 1903.—Called to order at 8.30 p.m. by Director George H. Wallis.

The minutes of the last regular meeting were read and approved.

The following gentlemen, having received the requisite number of ballots, were duly elected to membership in the Society: Augustus Kempkey, Jr., civil engineer; R. W. Myers, electrical expert; J. J. Welsh, architect.

The following applications were made and referred: Lewis Albert Hicks, civil engineering contractor, proposed by Stetson G. Hindes, D. C. Henny and Otto von Geldern; Charles List, civil engineer, proposed by C. E. Grunsky, Hermann Kower and E. T. Schild.

Mr. Emile Villet appeared before the Society, through his representative, and discussed his method of driving piles and building wharf structures of armored concrete.

This was followed by a detailed description of the Holmes and Uhlig method of building piers for wharf construction, consisting of a pile cluster, protected by a concrete mantle within a wooden-stave cylinder placed over the pile structure.

Mr. Carl Uhlig, who elucidated this method, dwelt upon all the features of its construction, and from his extensive experience in harbor work in San Francisco, called the attention of the members to actual examples where this effective method had been employed with success.

After discussing wharf building and pile driving as applicable to our local conditions, the meeting adjourned.

Otto von Geldern, *Secretary.*

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XXX. MAY, 1903. No. 5.

PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, APRIL 15, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.30 P.M.

President Ira N. Hollis in the chair; 35 members and visitors present.

The record of the annual meeting of March 18th was read and approved.

Messrs. Gage Haselton, Hector J. Hughes, Robert S. Weston and George H. Wetherbee, Jr., were elected members of the Society.

The Secretary reported for the Board of Government that it had appointed the following committees:

On Excursions—H. K. Higgins, F. M. Miner, E. P. Adams, G. A. King and W. L. Clark.

On the Library—F. P. McKibben, F. I. Winslow, J. N. Ferguson, K. S. Sweet and L. J. Johnson.

On Quarters—Desmond FitzGerald, E. W. Howe, C. F. Allen, E. W. Bowditch and H. Bissell.

On Advertisements—E. W. Howe, A. S. Glover and F. V. Fuller.

Members of the Board of Government in addition to the Secretary, J. R. Freeman, Henry Manley, Dexter Brackett and Dwight Porter.

The President announced the death of George R. Hardy, a member of the Society, which occurred on April 2, 1903, and on motion the President was requested to appoint a committee to prepare a memoir. The President has appointed as the committee, Messrs. L. B. Bidwell, Walter Shepard and E. K. Turner.

Mr. Brooks offered the following votes:

"Voted: That the Committee on By-laws, appointed at the last meeting, be requested to consider and report to the Society what changes, if any, should be made in the Constitution and By-laws to carry into effect the suggestions made by President Kimball in his address at the annual meeting in relation to broadening the work of the Society and increasing the interest of its members."

"Voted: That the President be requested to appoint four additional members on the Committee on By-laws."

After a short discussion in which Messrs. Howland, Tinkham, Porter and Hodgdon took part, and a motion to lay the matter on the table which was lost, the original votes were carried.

The President has appointed the following as additional members of the committee: G. A. Kimball, F. W. Dean, E. F. Miller and Sidney Hosmer.

The President stated that word had been received from Dr. Duncan, who was to read the paper of the evening, that owing to illness it would not be prudent for him to leave his house on so stormy a night.

On motion, the Society adjourned. S. E. TINKHAM, *Secretary.*

Detroit Engineering Society.

DETROIT, MAY 8, 1903.—The meeting was called to order at the Hotel Ste. Claire by President E. E. Haskell at 8.20 P.M.

Fred O. Ray, S. C. Root and Clyde Potts were recommended for membership by the Executive Committee, and upon motion of C. J. O'Hara and B. E. Parks, the Secretary was instructed to cast the unanimous ballot of the Society, and the President declared them elected to full membership.

Warren S. Blauvelt, of Grosse Isle, was proposed for membership by J. D. Sanders.

The annual reports of the Secretary-Treasurer were read, and, upon motion of O'Hara-Pope, accepted and ordered placed on file.

The President appointed S. G. Barnes, J. F. Lewis, C. G. Wrentmore and H. F. Johnson as tellers, and the Society proceeded to elect the following officers for the ensuing year:

President—F. C. McMath.

First Vice-President—T. H. Hinchman, Jr.

Second Vice-President—Antonio C. Pessano.

Secretary-Treasurer—Clarence W. Hubbell.

The business session of the Society was immediately followed by the ninth annual banquet, at which the following members were present: S. G. Barnes, E. E. Bratton, E. Cederstrom, A. F. Dierkes, J. H. Galwey, Hugh B. Gunnison, Edgar Hewitt, W. J. Keep, J. F. Lewis, F. H. Mason, E. W. Nicklin, Henry Penton, John A. Rathbone, Walter S. Russel, Herbert C. Sadler, Francis C. Shenehon, G. S. Williams, C. J. O'Hara, H. T. Morley, C. A. Pohl, F. S. Bigler, W. E. Brinkerhoff, A. L. Colby, Chas. Y. Dixon, W. J. Graves, E. E. Haskell, C. W. Hubbell, H. G. King, W. A. Livingstone, Geo. Mattson, Geo. E. Parks, Antonio C. Pessano, A. B. Raymond, Gordon Rutherford, J. D. Sanders, F. F. Van Tuyl, Geo. Y. Wisner, J. A. Ubsdell, Theodore Zealand, Theodore L. Miller, Major W. H. Bixby, Chas. E. Calder, Jos. B. Davis, Alex. Dow, R. B. Green, C. G. Herbert, H. F. Johnson, W. C. King, F. C. McMath, T. F. McCrickett, B. E. Parks, Willard Pope, Geo. A. Robinson, L. C. Sabin, William Scott, C. L. Weil, C. G. Wrentmore, Wm. McDonald, Forest Lancashire and the following guests: Mr. Smith, A. C. Lane, M. Doetling, J. J. Hubbell, Jr., H. Mengel, Boyd Ehle, L. Hennes.

The retiring President, E. E. Haskell, presided at the banquet, and the following toasts were responded to: "The Future of the Society," Mr. Walter S. Russel; "The University of Michigan," Professor J. B. Davis; "Our Naval Architects and Marine Engineers," Dr. Herbert C. Sadler, University of Michigan; "Our Electrical Engineers," Mr. Alexander Dow; "The Michigan Agricultural College," Prof. Chas. L. Weil; "The Corps of Engineers, U. S. A.," Major W. H. Bixby; "When he was Secretary," Prof. Gardner S. Williams.

The Schubert Quartet, Messrs. H. Mengel, A. F. Dierkes, L. Hennes and M. Doetling, rendered several choice selections.

CLARENCE W. HUBBELL, *Secretary.*

Engineers' Club of Minneapolis.

166TH MEETING, MINNEAPOLIS, MINN., APRIL 20, 1903.—The meeting was called to order by President Avery, in the County Commissioner's rooms at the Court House. About forty-five members and visitors were present.

The following new names were proposed for membership: Clinton B. Smith, D. A. Allee, W. S. Amy, K. F. Lundholm, J. J. Sheldon, Geo. Voelker, M. G. Hyde, R. L. Elliott.

The following were elected to membership: Floyd E. Cates, W. T. Conant, Henry Hoke, Leslie E. Benson, H. W. Bennicke, John Gemlo, J. R. W. Ambrose, Frank D. Chase.

Mr. Carroll handed in his resignation as Librarian, which was accepted, and Mr. Redfield appointed a committee of one to draw up suitable resolutions. It was moved and carried that a committee be appointed to investigate and present recommendations as to the disposal of the library. Mr. Avery appointed a committee of the following: Stoopes (chairman), Bellin, Hoag, Durham and Burch.

The program of the evening was then taken up. Mr. Redfield delivered a paper on the Panama Canal. Mr. Gillette recited some of his experiences on his recent trip through the West Indies.

The Club then adjourned. JAS. B. GILMAN, *Secretary.*

167TH MEETING, MINNEAPOLIS, MINN., MAY 22, 1903.—This month being the twentieth anniversary of the organization of the Club, the event was celebrated by a "Smoker" and entertainment at the hall, No. 15 South Seventh street. A short business meeting preceded the entertainment. The minutes were read and approved.

The following names proposed at the last meeting were duly elected to membership: Clinton B. Smith, W. S. Amy, K. F. Lundholm, J. J. Sheldon, Geo. Voelker, M. G. Hyde, R. L. Elliot.

The following names were proposed for membership: Fred. W. Stevens, C. H. Burrows, O. R. Boehm, H. A. Fitch.

Under a suspension of the rules, these men were elected to membership.

The committee engaged upon the Louisiana Purchase Exhibit reported progress.

Hon. W. H. Eustis delivered an address upon the Hawaiian Islands, to which he recently made a visit on a Government commission.

The Society was also entertained by Hilyard's Colored Quartet.

Light refreshments were served.

About seventy-five members and guests were present.

JAMES B. GILMAN, *Secretary.*

Association of Engineering Societies.

Vol. XXX. | June, 1903. | No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, May 20, 1903.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, at 7.45 o'clock p.m., President Hollis in the chair; fifty-six members and visitors present.

Record of the last meeting was read and approved.

Messrs. Louis F. Buff, Nathaniel W. Gifford, Samuel F. Jacques and John H. Kinealy were elected members and Gottfred G. Ledder an associate of the Society.

The committee appointed to consider the adoption of a badge for the Society submitted the following report:

"At the annual meeting of the Boston Society of Civil Engineers it was voted to appoint a committee of three to consider the adoption of a badge for the Society and to submit a design for the same, and the Chair appointed Isaac Rich, Alfred E. Burton and Richard A. Hale on the committee, which committee respectfully submit the following report:

"The committee have considered that a suitable badge would add to the dignity and standing of the Society.

"In selecting the design for the badge it was desired to obtain something not only original, but exemplifying in some degree the occupation of the members of the Society. Any design consisting of a shield in any form was at once discarded, as well as designs having a generally blue appearance, as these would be too much like the badge of the American Society of Civil Engineers. It was proposed to make the color a dark maroon, but this rather trespassed on the Harvard color. To make it a dark green was too much like the Dartmouth colors, and much black and gold was rather on the shade of the Princeton colors, if the two shades were in about equal parts.

"The committee finally decided on a design, the general shape and form of a plummet or plumb-bob, but flattened, so as to be used as a pin or watch-charm, the body of the badge to be of dull gold, with the name 'Boston Society Civil Engineers,' with the date '1848' in between the first two and the last two words. This was considered to fill all the requirements, appearing well, both as a pin, and in the case of one of the members having a pin of some other society it could be worn as a watch-charm. It was not conspicuous, and the cost reasonable, being $2.50 as a pin and $3 as a watch-charm, with the name of the owner and number on the back, the badge to be of solid gold, with the Society's name and date in black enamel. The committee also submit, as an alternative design, a pin representing the upper part of the so-called Boston Rod. This design forms a part of the Society's seal, and therefore would be appropriate as a badge of the Society. The committee suggest that each badge be registered, and be obtained of the

manufacturer on an order from the Secretary of the Society, each member obtaining his badge direct from the manufacturer.

"It is suggested that the oldest Past President be given badge No. 1, and the numbering to follow through the officers in the order of their holding office, and then the members in order of seniority according to the date of their joining the Society.

"Respectfully submitted,

"Isaac Rich.
"Alfred E. Burton.
"Richard A. Hale."

It was voted to accept the report and continue the committee.

On motion of Mr. Rice, as amended by Mr. Hodgdon, it was voted to authorize the committee to have prepared sample badges of each of the three designs and present them to the Society at a future meeting; that a circular be sent out with the notice of the meeting at which the designs will be on exhibition, giving the report of the committee and showing by cuts the designs of the badges and the probable cost of each.

Mr. L. F. Rice brought to the attention of the Society the Pich Process for brazing cast iron, which seemed to him to possess features that would make it of great utility to the engineering profession. The process consists of the use of a flux and a soldering compound invented and patented by Friedrich Pich, a German subject, resident of Berlin, Prussia. In this country shop and territorial rights to use the process may be obtained from the American Ferrofix Company, owners of the patent for the United States, but actual work of repairing is done by the American Brazing Company, which is operating repair shops in several of the larger cities. The Boston shop is located at 172 Oliver Street, where the process may be seen in practical operation.

Wishing to witness the operation of brazing and to test its efficiency, Mr. Rice procured a cast-iron standard which was about 12 inches long by ⅜ inch thick, and varied in width from 11-16 inch to 3 inches. At a point where the width was 1¾ inches there was a screw hole ⅛ inch diameter by ¼ inch deep. This casting was placed upon an anvil and broken in two places by blows with a hammer. One of the fractures passed through the screw hole and at the other the standard was 17-16 inches wide. As an additional test of the efficiency of the process, one face of the longer fracture was smeared with oil and dirt and the other with asphalt varnish. The broken and befouled standard was then taken to the repair shop at 172 Oliver Street, where the operation of brazing was performed, occupying about fifteen minutes. Later the standard was again placed upon an anvil and struck with a hammer upon the shorter of the newly brazed joints. The blow caused two new breaks, one on each side of the brazed fracture, but neither approaching it within ⅛ inch. The longer brazed joint being struck, a new fracture developed, beginning about 1-16 inch from one side of the brazing, extending thence to the screw hole, where it crossed to the opposite side of the original fracture and thence continued to the other edge of the standard. Both faces of the new fracture show clean cast-iron surfaces, with no traces of the brazing except in the screw hole, although the new break is mostly within 1-32 inch of the brazed joint.

The standard used in the experiment was then passed around for the inspection of the members of the Society, together with a sketch showing the shape of the standard and the location of the various fractures. The sketch is here reproduced.

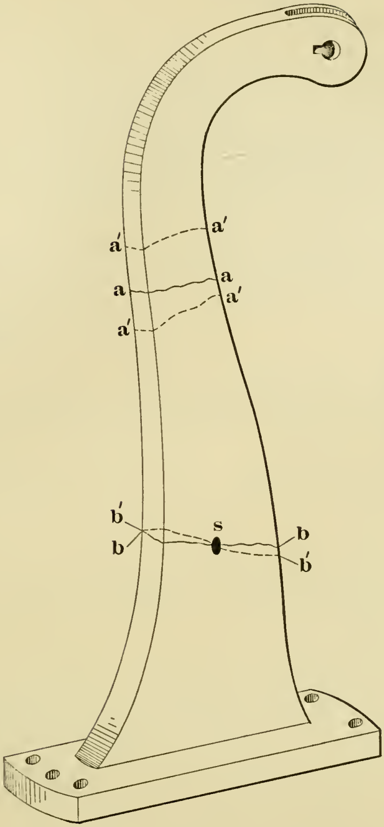
CAST-IRON STANDARD.

Broken at a and b and brazed by Pich process.

Again broken by hammer blows upon brazed joints.

Double fracture a'-a' was on both sides of brazing.

Fracture b'-b' crossed brazed joint at screw hole s.



Height = 12″.
Thickness = $\frac{3}{8}''$.
Width $a = 1\frac{17}{16}''$.
Width $a' = \frac{15}{16}''$ and $1\frac{19}{16}''$.
Width b and $b' = 1\frac{3}{4}''$.
s = screw hole.
$\frac{1}{8}''$ diameter.
$\frac{1}{4}''$ deep.

Several instances were cited showing the wide range of cases where the Pich process could be made available and the saving of time and money that could be accomplished by its use. In one case the value of a new piece of machine to replace a broken one was $18, but the delay necessary to procure a new piece involved money loss of a much larger sum. The broken piece was repaired by the Pich process, for which $5 was charged and cheerfully paid. The work of repair took ten minutes and cost eight cents.

A year or more ago the United States naval floating repair shop *Vulcan* was refitted at the Charlestown Navy Yard. The day before she was to sail a heavy warping block, which had been broken in two and repaired by bolting on a plate, was found to be in an unsafe condition. As the ship had been bought in Europe during the Spanish War, our Government had no duplicate parts and no models from which to cast any. To remove the broken warping block and use it as a model for a new casting would involve a detention of the ship for two or three weeks. In this dilemma the American Brazing Company was applied to, who sent men and tools to the Navy Yard and brazed the broken block in less than three hours, so that it was used in warping the ship from her moorings when she sailed the next morning for the Philippines, where she is now stationed.

By accident a spoke was broken from a fly-wheel, 19 feet in diameter, 48 inches width of rim, weighing 21 tons. A new wheel would have cost $2700 and would have involved two or three months' delay. The Pich process was applied; men and apparatus were sent to the wheel; the broken spoke was brazed into place, and $250 charged and paid for the job. The actual cost of doing this work was less than $50.

The paper of the evening, "The Electrical Transmission of Power," was then read by Dr. Louis Duncan, professor of electrical engineering at the Massachusetts Institute of Technology. The paper was illustrated by numerous lantern slides.

On motion of Mr. Kimball, it was voted to hold the next regular meeting on some other date than the 17th of June, if, in the opinion of the President and Secretary, it seems advisable.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, Mass., June 24, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., Vice-President Frederick Brooks in the chair; one hundred and ten members and visitors present.

The record of the last meeting was read and approved.

Mr. Horace Ropes was elected a member and Mr. Wilbur S. Locke an associate of the Society.

Mr. Rich, for the committee on badge, made a verbal report, giving the prices at which the badges could be obtained, and presented a sample of each of the three badges described in the report submitted at the last meeting. The report was accepted.

The committee appointed to prepare a memoir of our late associate, George R. Hardy, presented its report, which was read by the Secretary.

The Chair announced the death of Alphonse Fteley, a member of the Society, which occurred on June 11, 1903, and, on motion of Mr. Adams, the President was requested to appoint a committee to prepare a memoir. The President has appointed as this committee Messrs. Joseph P. Davis, Frederic P. Stearns and George S. Rice.

The thanks of the Society were voted to the Hon. Charles P. Bennett, Secretary of the State of Rhode Island; to Mr. Charles S. Chapin, Principal State Normal School, Providence; to Messrs. C. W. Blakeslee & Son, contractors for grade crossing work at Fall River, and to Mr. A. S. Tuttle, assistant engineer, New York, New Haven and Hartford Railroad, for courtesies shown members of the Society on the occasion of the visit to Providence and Fall River on June 17, 1903.

Mr. John R. Freeman then gave an exceedingly interesting and instructive talk on "Problems Connected with the Proposed Charles River Dam." The talk was fully illustrated by lantern slides.

Adjourned. S. E. Tinkham, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., May 1, 1903.—Called to order at 8.30 p.m., by President Henny.

The minutes of the last regular meeting were read and approved.

Mr. L. A. Hicks was announced a duly elected member of the Society after a count of ballots.

Mr. Marsden Manson, by general request, addressed the members informally on the various projects for a water supply for San Francisco, which, proving of vital interest to local engineers, he promised to continue at the next regular meeting of the Society.

Mr. Elwood Mead, Chief of Irrigation Investigation of the United States Department of Agriculture, then spoke at length of the work—past, present and future—of his department in California, and of the results reached and those aimed at, in order to obtain reliable data upon which to base all future engineering work, such as the duty of water per acre, the percentage of evaporation and seepage, elements extremely difficult to determine without extensive systematic study and experiment, and the methods of getting rid of leakage overflow.

The interesting topic was discussed at length by many of the irrigation engineers present.

The President thanked Mr. Mead, in the name of the Society, for his courtesy.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

EXCURSION OF THE SOCIETY.

On the 23d of May the Society was invited by Messrs. Nathan L. Bell and Morris Kind to visit the works of the Pacific Portland Cement Company, at Suisun, Cal.

A special train conveyed the party of about sixty members from the Oakland wharf to the works, where they were shown the limestone quarry, the clay field, the conveyors to the mill and the various processes of manufacture, by following the raw material from the quarries through all the various stages to its final condition as marketable product.

At a luncheon prepared by the officers of the company, President Henny expressed the appreciation of the Technical Society for the courtesy of the gentlemen who had prepared and arranged this instructive and interesting excursion.

General Stone, the President of the company, responded and welcomed the members, requesting them to examine critically any and every part of the works, the output of which was about to be increased from seven hundred to fourteen hundred barrels per day.

The train left the works at four o'clock, returning to San Francisco with the members of the Society.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

563d Meeting, St. Louis, May 20, 1903.—Held at the Club Rooms, 709 Pine street, at 8.15 p.m., President Van Ornum in the chair; present twenty-nine members and five visitors.

The minutes of 562d meeting were read and approved.

The minutes of the 348th meeting of the Executive Committee were read.

The following gentlemen were on ballot unanimously elected to member-

ship: Messrs. Henry Rohwer, L. Ravenswaay, John A. Garcia, John E. Walker and A. O. Cunningham.

It was moved, seconded and carried that the Engineers' Club authorize Mr. Ockerson to extend an invitation to the American Society of Civil Engineers to hold their annual convention at St. Louis in 1904.

It was moved, seconded and carried that the Club indorse the report of the King's Highway Boulevard Commission.

It was moved, seconded and carried that the report of the Committee on Engineering Index be referred to the Executive Committee with full power to act, and that for this purpose the Librarian be added to the Executive Committee.

Mr. A. L. Johnson, reported progress on the part of the Committee on Affiliated Societies and asked to have the committee continued through the summer. The Chair ruled that the committee remained in existence until discharged without special action by the Club.

The paper of the evening was then read by Mr. John E. Conzelman on the "Plant of the St. Louis Portland Cement Company."

The description was very thorough and instructive. In addition he also described the method of the manufacture of Portland Cement. The paper was illustrated by maps, photographs, tables of tests and chemical analysis of the product and raw material of this mill.

An interesting discussion followed which was participated in by Messrs. Hermann, Russell, Moreno, Affleck, Van Ornum, Pitzman and Greensfelder.

A vote of thanks was unanimously tendered to Mr. Conzelman for his excellent paper.

Upon motion the meeting adjourned.

H. J. Pfeifer, *Secretary.*

564th Meeting, St. Louis, June 3, 1903.—Held at the Club Rooms, 709 Pine street, at 8.15 p.m., President Van Ornum in the chair; present twenty-four members and eight visitors.

The minutes of the 563d meeting were read and approved. The minutes of the 349th meeting of the Executive Committee were read.

The minutes of the 17th meeting of the Governing Board of the Associated Technical Clubs were read.

It was moved by Mr. Layman, seconded and carried, that a vote of thanks be given to Mr. J. C. Robinson and the St. Louis Portland Cement Company, to Mr. L. F. Goodale and the Burlington Railroad, to Mr. W. S. McChesney and the Terminal Railroad Association, and to Mr. H. L. Magee and the Wabash Railroad for courtesies extended to the Club on May 30, 1903, the occasion of its visit to the St. Louis Portland Cement Company's Works and the West Belt Line of the Terminal Railroad Association.

The Secretary announced that the members of the Club were invited to attend the meeting of the local Chapter of the American Institute of Electrical Engineers on Wednesday, June 10, 1903, at the Club Rooms, the paper for that evening being by Mr. Adams on the "Heyland Induction Motor."

It was moved by Mr. Wheeler, seconded and carried, that a vote of thanks be given to Jean Jameton and to Mr. Hugnes Brussel for the invitation to be present at the test of the Hennebique System of Armored Concrete construction which is to take place at the Wm. McKinley High School on Tuesday, June 9, 1903.

The paper of the evening by Mr. A. S. Langsdorf on the "Heyland Induction Motor," was then read. Mr. Langsdorf fully explained the motor and showed its theoretical advantages over the present form of motor. He said, though, that at the present time on account of the complicated nature of the machine, he did not think it commercially available. The paper was illustrated by a number of charts and diagrams. The paper was discussed at some length by Messrs. Layman and Langsdorf.

Mr. Bryan on behalf of the local membership of the American Society of Mechanical Engineers and of the American Society of Heating and Ventilating Engineers, asked the Club to join in an invitation to these bodies to hold their 1904 conventions in St. Louis, provided their local members decided to invite them to come. It was moved, seconded and carried that the Club do this. There being no further business the meeting adjourned to the lobby where a light lunch was served.

H. J. Pfeifer, *Secretary.*

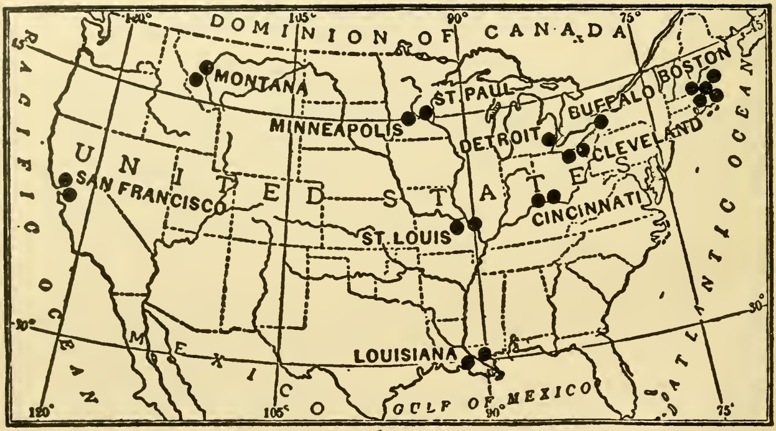
Montana Society of Engineers.

The regular meeting of this Society, for May, was held on the 9th inst., with Vice-President Moulthrop in the chair. A quorum present. The minutes of the April meeting were read and approved. The committee having in charge the matter of binding the various periodicals belonging to the Society reported progress and asked for further time, which was granted.

Owing to the unavoidable absence of the author, Mr. M. H. Gerry's paper on the "50,000-Volt Transmission Plant and System of the Missouri River Power Company" was read by the Secretary, after which the details of the plant were fully explained by Mr. W. L. Miller, the resident representative of the company in Butte. The various phases of this and other electric power transmission systems were discussed by Messrs. Hebgen, Sickles, Magnus, Traphagen and others. Mr. Gerry's paper was then referred to the trustees with a request on the part of the Society for publication in the Journal of the Associated Societies.

After a vote of thanks to Messrs. Gerry and Miller, the Society adjourned.

Clinton H. Moore, *Secretary.*



DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
ST PAUL
MINNEAPOLIS
DETROIT
BUFFALO
BOSTON
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
30°
45°

LISTS OF MEMBERS

OF THE SOCIETIES COMPOSING THE

Association of Engineering Societies.

DECEMBER 31, 1902.

Lists of Members of the Associated Societies.

Abbreviations for designating membership:

MEM. . . . . FOR MEMBER.
HON. MEM. . . . . FOR HONORARY MEMBER.
ACT. MEM. . . . . FOR ACTIVE MEMBER.
ASSOC. MEM. . . . . FOR ASSOCIATE MEMBER.
COR. MEM. . . . . FOR CORRESPONDING MEMBER.
JUN. MEM. . . . . FOR JUNIOR MEMBER.
ASSOC. . . . . FOR ASSOCIATE.
JUN. . . . . FOR JUNIOR.

Boston Society of Civil Engineers.

ADAMS, EDWARD P., Mem.,
Landscape Architect and Civil Engineer,
53 State street, Room 1105, Boston, Mass.

ADAMS, HENRY S., Mem.,
Civil Engineer, 53 State street, Room 542, Boston, Mass.

ADDICKS, WALTER R., Mem.,
Chief Engineer, Boston, Bay State, Roxbury and South Boston Gas Companies, 24 West street, Boston, Mass.

AIKEN, CHARLES W., Mem.,
Consulting Engineer, 82 Washington street, New York, N. Y.

AIKEN, ROY C., Mem.,
Civil Engineer, cor. Atlantic and Prospect streets, Atlantic, Mass.

ALLARD, THOMAS T., Mem.,
Civil Engineer, Fort Caswell, N. C.

ALLEN, C. FRANK, Mem.,
Professor of Railroad Engineering, Mass. Inst. of Technology,
Boston, Mass.

ALLEN, CHARLES A., Mem.,
Consulting Engineer, 44 Front street, Worcester, Mass.

ANDREWS, DAVID H., Mem.,
President, Boston Bridge Works, 47 Winter street, Boston, Mass.

ARMSTRONG, SAMUEL G., Mem.,
Civil Engineer,
Kimberley Villa, Harrington street, Cape Town, South Africa.

ASPINWALL, THOMAS, Mem.,
Aspinwall & Lincoln, Civil Engineers,
120 Tremont street, Room 606, Boston, Mass.

Atwood, Joshua, 3d, Mem.,
Chief Engineer, Paving Division, Street Department, Boston.
70 City Hall, Boston, Mass.

Badger, Frank S., Mem.,
Civil Engineer, 28 Bellevue street, Lowell, Mass.

Bailey, Ernest W., Mem.,
City Engineer, City Hall, Somerville, Mass.

Bailey, Frank S., Mem.,
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Bailey, William M., Mem.,
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Baldwin, Loammi F., Mem.,
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Bancroft, Lewis M., Mem.,
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Barbour, Frank A., Mem.,
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Barnes, Rowland H., Mem.,
Pierce & Barnes, Civil Engineers, 7 Water street, Boston, Mass.

Barnes, T. Howard, Mem.,
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Barnes, William T., Mem.,
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Residence, 773 Broadway, South Boston, Mass.

Barney, Percy C., Mem.,
Draftsman in charge, Dept. of Yards and Docks, U. S. Navy Yard, Boston, Mass.

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Assistant in City Engineer's Office, City Hall, Lowell, Mass.

Bartlett, Charles H., Mem.,
Counsellor at Law and Consulting Engineer,
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Bartram, George C., Mem.,
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153 Milk street, Boston, Mass.

Bateman, Frederic W., Mem.,
Parker & Bateman, Civil Engineers, Clinton, Mass.

Bateman, Luther H., Mem.,
Assistant Engineer, Harbor and Land Commissioners,
131 State House, Boston, Mass.

Bayley, Frank A., Mem.,
Civil Engineer, 133 Austin street, Cambridgeport, Mass.

Bement, Robert B. C., Mem.,
Civil Engineer and President, Board of Water Commissioners,
St. Paul, Minn.

Betton, James M., Mem.,
with C. W. Hunt Co., West New Brighton, N. Y.

Bidwell, Lawson B., Mem.,
District Engineer, Eastern District, N. Y., N. H. and H. R. R.,
South Station, Boston, Mass.

Bigelow, James F., Mem.,
City Engineer, City Hall, Marlboro, Mass.

Bissell, H., Mem.,
Chief Engineer, Boston and Maine Railroad, Boston, Mass.

Blake, Francis, Mem.,
Auburndale, Mass.

Blake, Percy M., Mem.,
Civil and Hydraulic Engineer, Newtonville, Mass.

Blodgett, George W., Mem.,
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Blood, John Balch, Mem.,
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Sanitary Engineer, with S. Homer Woodbridge Co.,
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Engineer, Sewerage Commissioners, Adams Bldg., Quincy, Mass.

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Burke, John R., Mem.,
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Burr, Thomas S., Mem.,
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Chamberlain, Edward G., Mem.,
Topographical Surveyor, Auburndale, Mass.
Chamberlain, William G. S., Mem.,
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Chambers & Hone, Consulting Engineers,
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Chapman, William H., Mem.,
Waring, Chapman & Farquhar, Civil Engineers,
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Chase, John C., Mem.,
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Wilmington, N. C.
Cheever, Albert S., Mem.,
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Boston, Mass.
Cheney, John E., Mem.,
Assistant City Engineer, City Hall, Boston, Mass.
Clapp, Otis F., Mem.,
City Engineer, City Hall, Providence, R. I.
Clapp, Sidney K., Mem.,
Civil Engineer, 106 Johnson street, Waterbury, Conn.
Clapp, Wilfred A., Mem.,
Civil Engineer, Quartermaster's Dept., U. S. A., Diamond, Island,
Portland, Me.
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Residence, 50 Sacramento street, Cambridge, Mass.
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Coggeshall, Robert C. P., Mem.,
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Cook, Mayo T., Mem.,
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CORTHELL, ELMER L., Mem.,
Consulting Engineer, 1 Nassau, street, New York, N. Y.

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CRANE, ALBERT S., Mem.,
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CROWELL, ALONZO K., Mem.,
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CUMMINGS, W. WARREN, Mem.,
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CUNNINGHAM, FRED'K H., Mem.,
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CUNTZ, WILLIAM C., Mem.,
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CURTIS, GREELY S., Mem.,
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Bristol street, Boston, Mass.

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CURTIS, LOUVILLE, Mem.,
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CUTTER, CHARLES R., Mem.,
148 Ruthven street, Roxbury, Mass.

CUTTER, LOUIS F., Mem.,
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Residence, 33 Chestnut street, Salem, Mass.

CUTTER, ROLAND N., Mem.,
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A CENTURY'S PROGRESS IN ENGINEERING EDUCATION IN THE UNITED STATES.

BY ROBERT HEYWOOD FERNALD, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, February 18, 1903.*]

THE past century has been a period of special significance in the development of technical education, and is properly regarded as the era of its most important advancement. Reviewing the history of this period, we find ourselves, even at its beginning, a long way from the original source of technical education, which is, in fact, prehistoric. A brief sketch of the earliest known results of this type of education is of value as revealing the foundation of its more recent accomplishments.

The Bible states that Tubal-Cain, the inventor of the art of forging metals, was "an instructor of every artificer in brass and iron"—and this nearly 4000 years B.C. The building of the great cities of the ancients required a knowledge of materials and methods of construction which seem marvelous to-day, and manufacturing and other industries must have formed a necessary part of the evidently active life of ancient communities. The cutting of the great monoliths from the quarries of Syene, together with the inscriptions wrought upon their faces; the raising of these huge masses of stone to form the pyramids; the building of great tombs in these structures, as well as the excavating into the mountains of the region for a like purpose, and the application of the mechanic arts in ways more refined and delicate, but nevertheless enduring, lead directly to the conclusion that the foundation of technical training and a knowledge of technical principles are as old as civilization; and in tracing the history of engineering

*Manuscript received June 6, 1903.—Secretary, Ass'n of Eng. Socs.

education in any country one is taken back to the ancient cities of Assyria, Babylonia, India, Egypt, Greece or Italy.

Some 1500 years B.C. a great university, supported by the Pharaohs, is shown to have existed by records since found. Dormitories, for those able to pay the necessary fees, were erected. Over eight hundred instructors were enrolled as members of the faculty, and schools of art, painting, sculpture, architecture and engineering, so far as developed, were included within this wonderful institution.

As early as 1300 years B.C. the University of Rameses was planned, and one thousand or more years later the great University of Alexandria was founded. In this latter university technical education seems to have been a more prominent feature, and more than ever before was there an effort to give instruction in all the forms of the arts, literature and sciences, and the modern sciences can easily be traced back to these ancient efforts. The work of Plato, Aristotle, Archimedes and Euclid was directly in the line that eventually developed into the various technical branches. These men and their associates had much to do in originating and investigating the scientific theories of that day, and many of their conclusions have stood the tests of time.

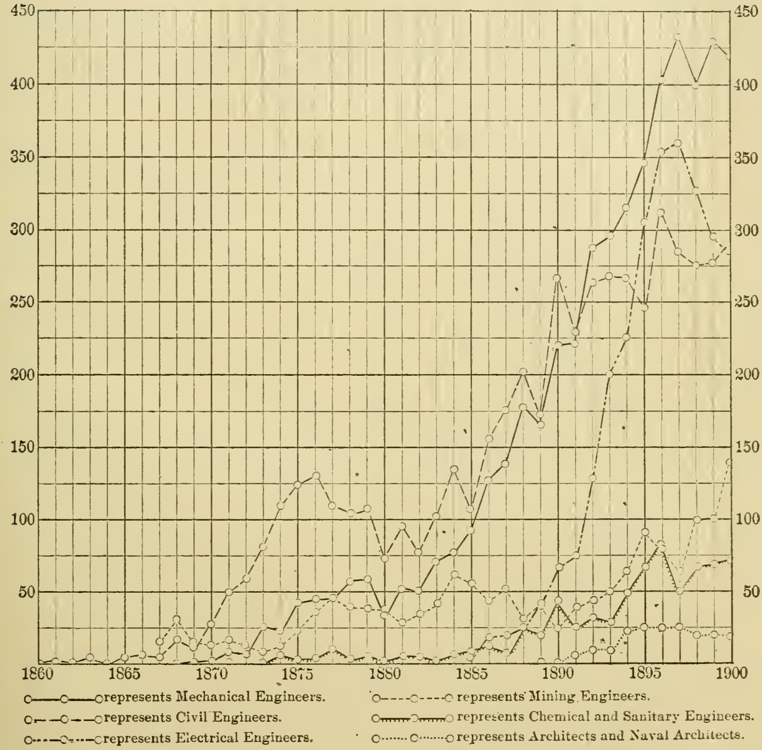
It was Galileo who, in 1590 A.D., ventured to question the possible mistakes in Aristotle's statements, and to him dynamic engineering owes its possibility. To the priest and monk is due the credit of having kept alive the mechanic arts during many centuries, for it was through the church that educational movements and developments were kept from total destruction.

What is to-day called the new education is really not new, but simply a recent revival and development of an education which dates back many hundred years before the Christian era; for, as Riedler has said in disputing the fact that medicine was the oldest science, "older still is technical development: civilization began with man."

It is not the purpose of this paper to trace the development of engineering education as a whole, but rather to note the progress of such education in the United States.

Before beginning the historical portion which applies to the United States alone it is of interest to inquire what is regarded as the proper education for an engineer, and later to observe, as far as space will permit, the conditions prevailing in the technical institutions of this country, to ascertain whether these institutions are doing all in their power to meet the educational demands of the present generation of engineering students.

To educate her youth should be one of the highest privileges of any state. Whether in peace or in war, the engineer is found to be an indispensable factor in a nation's efficiency. Naval battles are fought by the engineer, the manipulation of the land forces is possible only through the work of the engineer, and, in times of peace, manufacturing, commerce, and, in fact, nearly all the arts and sciences depend upon the engineer. What is more natural than the tendency of a large percentage of the young men of to-day to train themselves along the lines offering such vast opportunities?



NUMBER OF GRADUATES IN THE SIX ENGINEERING DEPARTMENTS FROM 1860 TO 1900, INCLUSIVE.

What, then, should be the nature of this education? Should the engineer be a specialist only, or should he have a broad and liberal education coupled with special training?

Ruskin says that "An educated man ought to know these things: First, where he is—that is to say, what sort of a world he has got into, how large it is, what kind of creatures live in it, and how; what it is made of, and what may be made of it. Secondly, where he is going—that is to say, what chances or reports

there are of any other world. Thirdly, what he had best do under the circumstances—that is to say, what kind of faculties he possesses; what are the present state and wants of mankind; what is his place in society, and what are the readiest means in his power of attaining happiness and diffusing it. The man who knows these things and who has his will so subdued in the learning of them that he is ready to do what he knows he ought, is an educated man, and the man who knows them not is uneducated, though he could talk all the tongues of Babel." Even after settling to his own satisfaction these three conditions of Ruskin it is still a difficult question for a young man to determine what should be his courses of study best to prepare him for the greatest usefulness and the highest possibilities.

It must be borne in mind that an education is not a collection of facts stored away, to be drawn upon as desired and used as mere facts with no development or improvement, but rather a condition of the mind which enables one to develop systematically and symmetrically such problems and conditions as may come before him for solution or investigation. This, it seems, marks the distinction between a special and a liberal education, the one giving a supply of facts and information, the other teaching the student to use his own powers of observation and judgment. It is Huxley who so well defines the liberally educated man. He says: "That man, I think, has a liberal education whose body has been so trained in youth that it is the ready servant of his will, and does with ease and pleasure all that, as a mechanism, it is capable of; whose intellect is a clear, cold logic engine, to be turned to any kind of work and to spin the gossamers as well as forge the anchors of the mind; whose mind is stored with the knowledge of the great fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions have been trained to come to heel by a vigorous will, the servant of a tender conscience; one who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to esteem others as himself."

This powerful description applies with equal force to the engineer, the clergyman or the man of letters, and no one aiming toward a life of great usefulness and power can question the superior strength and nobility of him who is able to follow such a course as shall develop as completely as the natural endowment of the individual will allow the broad, well-balanced and liberally educated man. This broad, liberal education produces a truer conception of the truth of existing laws, the application of better

judgment in thought and a clearness of apprehension and comprehension not possible in the case of the recipient of a narrow special education.

The engineer should be a man of large conceptions and sound judgment, with a thorough knowledge of the truths of nature and the ability to convert the results of her laws into channels best adapted to the needs at hand. His resources must be unlimited. His associations are such that culture and refinement are of great moment, and a well defined knowledge of the conditions and resources of the world at large is indispensable. Business training is also very essential, and, in fact, there is probably no other profession in which the cultivating influences of a general education are more necessary than for the man who has to cope with the greatest problems of civilization and progress—the engineer.

Is it possible for the average student of engineering to obtain such an education? It is, of course, necessary for him to be conversant with his special lines, and the average time taken for a college education will not admit of thorough training in one particular direction as well as years of unknown value that may be devoted to general and culture subjects. What the proportion should be and the order and relative value of different subjects is outside the province of this paper, but it will prove of interest to note later the general tendency, in this regard, of the engineering institutions of the United States. The more one studies the subject, the more information one gathers from those in positions of responsibility, and the more one watches the careers of young men, the more convinced does he become of the misfortune which has befallen those who have neglected the cultivating influences of such educational advantages as were within their reach. It is true that many a young man, through force of circumstances, cannot avail himself of the opportunities for such education, and is forced to fight his own way as best he can, securing only, if any at all, such special training and education as will best fit him for his particular chosen profession. Such a young man is unfortunate, but not to be blamed, and may far outstrip, both in natural ability and application, the young man of more desirable opportunities who has ignored his chances for development.

Misfortunes and difficulties do not necessarily strengthen a man. The strong man only can overcome such obstacles, and while he may, by virtue of his strength, accomplish much, yet it is a question whether the same man with such qualities would not have been even greater had he been allowed the opportunities and

privileges of a better and more liberal education. Much more estimable, however, is the man who has come up under such hardships than he whose ease and luxury have killed worthy ambition and have made the want of the best possible education a matter of indifference and neglect. In speaking of a liberal education, President Timothy Dwight, of Yale, has said: "He may not be a philosopher, or a poet, or a statesman, or a scholar; but as educated, and because he is educated, he is thoughtful, rich in his resources for himself and for others. This is what the higher education means, and it has no truest and deepest meaning apart from this. This developed power of serious thought is the essence of educated life. It is the fountain of living water within the mind, which is for every educated man the blessing of such life. To have rich thoughts, serious thoughts; in the sense of calm, serene, earnest, intelligent, cultured, generous, manly thinking on any and all themes which are worthy of human thought, what blessing for the mind can be greater, or can contain in itself more truly the secret of the best living?

"Who knows that results are greater when the man understands only one thing and thinks only one? The results that are seen may, perchance, be greater; though this, as relating to all cases, will need proving. But those that are unseen, who can tell of them? And the unseen results are often, if not always, the greatest and most important. In the unseen region is influence. It is itself, in the largest working and measure of it, the most unseen of all things. But what influence is, and from the nature of influence will ever be, so wide reaching as that of a rich mind and soul which are filled out by education on every side to their fullness of culture and beauty?"

Never has the lack of a college education been more keenly felt than by the young men of the present day who have either neglected opportunities or have been prevented from securing those advantages which are so gratifying to the educated and which money cannot buy. Sympathy is indeed due the young man who feels his lack of appreciation and knows his limitations to be due to the want of a proper education. Very few there are who would not give all they possess, when they realize their limitations, to feel that they had the power to discuss the momentous problems of the day with the educated and prominent men of the land, or could at least carry on a pleasing conversation with men of deep thought and keen perception. If in addition they can acquire the ability to appreciate the best literary, musical and artistic productions, the sacrifice is great that will not be made for such an end.

"The more one has the more one wants" is strikingly true in educational circles, and it is a question whether the average young man without a college education feels more keenly his lack than does the young man who has risen relatively higher, but has pursued a single narrow line, leaving out the subjects which tend to broaden his views and to open for him vast possibilities in the world of refinement and culture, because his absorption in the work of his own special field has entirely shut them from view. When he awakes to find himself far behind his more fortunate fellows, then he catches glimpses of the great opportunities that might have been his, had he but realized earlier the difference between the educated man and the man whose whole aim and study have been crampd into one narrow line. This is not saying that the specialist is not needed, and to-day more than ever before, but the specialist whose educational foundation is broad and liberal, who is a well-rounded man, who can appreciate the necessity of, and understand, in a general way, the work of others in fields which are possibly very remote from his own, is a man of larger resources and possibilities, and is a much greater power in the world than the mere specialist can be. His own special line need not suffer on account of his broad conception of life and study, but, on the contrary, the deductions and results of his specialized efforts will bear a truer and more direct relation to existing facts and conditions than otherwise would be possible. The following words from Bishop Henry Potter, delivered at the one hundredth commencement of Union College, at Schenectady, carry out this thought: "The time will never come when a man who has not merely learned certain chemical combinations so that he can manufacture a fertilizer, or certain mathematical combinations so that he can build a railroad, but has also learned what made a little peninsula in the Adriatic the mistress of the world, or how Roman law became the basis of the jurisprudence of Christendom, or how the fall of empires was foreshadowed in the 'Republic' of Plato, or how the growth of a corrupt and privileged ecclesiasticism brought about the transformation of modern Europe, the time will never come, I say, when the man who has learned these things, not a parrot-like learning, but in the length and breadth of their vast and enduring significance, will not be, in every highest sense, the master of him who has not."

Literature, languages, philosophy and mathematics do not make the well-rounded, cultured man any more than do special technical courses. The field of information and training is unlimited, and there is no one field or branch so broad that great

advantage cannot be gained by investigation in the others, and that man may count himself fortunate whose early years are well directed and well employed in the serious pursuance of study in the courses best fitted to develop and mold "the man," for that training is indisputably the most noble and most desirable which has for its aim the development of those faculties and powers which shall first make the student a man, and secondly fit to undertake work in his special lines.

To what extent this idea has been carried out by the engineering institutions of the United States can be shown only by a sketch of the growth of such institutions, and by observing the demand for and the success of young men whose lives have been molded in these engineering schools. The healthy growth of the technical school is marked with keen interest, and the following brief sketch of its development during the past century shows at once the imperative need of such institutions and the excellent quality of their work, together with the fact that progress in engineering education has kept pace with the development of the country.

At the very beginning of the nineteenth century the need of engineering education was felt, and the United States Military Academy at West Point, being the only institution fitted to give such training, took the initiative and in 1802 conferred degrees upon the first two engineers graduated in the United States.

*A few years later an effort toward engineering education was made by Thomas Jefferson, and, although he was unable to secure the carrying out of his plans, it is of interest to note his advanced ideas upon this subject, for in 1818 he included in an outline of the scope of higher education this expression: "To harmonize and promote the interests of agriculture, manufacturing and commerce, and to enlighten our youth with mathematical and physical sciences, which advance the arts, and administer to the health, the subsistence, and comforts of human life."

In attempting to organize the University of Virginia he so planned that four of its ten courses should be scientific. He spoke of it as "a school of technical philosophy" and desired instruction in "the sciences of geometry, mechanics, statics, hydrostatics, hydraulics, hydromechanics, navigation, astronomy, geography, optics, pneumatics, acoustics, physics, chemistry, natural history, botany, mineralogy and pharmacy," and also in writing of his plans said: "The use of tools, too, in the manual arts is worthy of encourage-

*Note.—Much of the following historical portion of this paper was taken from articles published in *Engineering News*.

ment by facilitating to such as choose it an admission into the neighboring workshops."

So closely allied with engineering training are the schools of manual training that the mention of the founding of the early schools is of interest historically. Probably the first institution of this class in the United States was organized in 1833 at Penfield, Ga. It was conducted by the Baptist church and was known as Mercer Institute. Prof. J. J. Wilmore, in writing of "Some Phases of Engineering Education in the South," adds in reference to Mercer Institute: "A student at that time, writing many years afterward, feelingly says: 'The work was on the farm. There was also a sort of mechanical department. A preacher thirty years old, parrot-toed, a carpenter—he bossed it. For a long time I worked at the whipsaw.'" This institution was followed by Wake Forest Institute the next year.

Not long after this a great advance in higher technical education was made, for in 1840 Rensselaer Polytechnic Institute, of Troy, N. Y., came to the front with the first civil engineers to be graduated, not only in the United States, but in any English-speaking country,—graduating a class of thirteen that year.

The opportunities of obtaining training in engineering lines previous to this time were very limited, as the only institution giving any such instruction was at West Point, and the only other means of obtaining any such education was by entering the office of some civil engineer. As this latter system "existed in New England, no formal articles were drawn, but the arrangement was understood to be for three years, during which period the student was charged $100 per year for his 'tuition' and was credited with the liberal sum of 12½ cents per hour for actual work in the field, office work being gratis." The terms varied at times, particularly "after the war," when office work received the same compensation as field work. The student was allowed to ask questions and to pick up what information he was able.

Previous to 1850 the important engineering positions were held largely by graduates of West Point, but since the establishment of the institutions especially adapted to give instruction in engineering lines this institution has furnished few engineers. Of the first thousand graduates of West Point some one hundred and fifty became civil engineers, but of the second thousand, only fifty, and since the class of 1863 few have become civil engineers of prominence.

The condition of the country prior to 1840 was such that there was little demand for engineers. There were practically no railroads and the general development was not such as to require the services of such men to any extent, outside, possibly, of the canals.

In founding Rensselaer Polytechnic Institute Hon. Stephen Van Rensselaer did much for the cause of engineering. The institution was founded by him in 1824-25, but in the first copy of the act of incorporation and in the constitution and laws of the school the word "engineering" or "engineer" does not appear. In 1828 these words made their appearance, as the senior professor was to lecture on "Chemistry, Natural Philosophy, Geology, Land Surveying, and Civil Engineering." It was October 14, 1835, that the first prospectus in English of a school of civil engineering was issued. Among other things it stated that the degree of civil engineer would be conferred upon "candidates of seventeen years and upwards who are well qualified in that department." "One year is sufficient for obtaining the Rensselaer degree of Bachelor of Natural Science, or of Civil Engineer for a candidate who is well prepared to enter. Graduates of colleges may succeed by close application during the twenty-four weeks in the summer term. Candidates are admitted to the Institute who have a good knowledge of arithmetic and can understand good authors readily, and can compose with considerable facility." "The degree of Master of Arts is conferred after two years of practical application." Rensselaer graduated from six to thirteen engineers a year, and these, with the few from West Point, made up the list of directly trained engineers for a period of some ten years, when the school of engineering of Union College entered the field in 1845, with the distinction of being not only the second engineering school, but the first to be organized as a branch of a classical college. The success of this institution was not marked, as it graduated only two or three students of engineering a year for a long period and remained very small until about 1860.

In 1846, the year following the organization of the engineering department of Union, the Lawrence Scientific School became a branch of Harvard University, and was the third institution to introduce engineering. The history of this institution has been until within a recent period most unfortunate, and in referring to it some writer has said: "By others' faults wise men correct their own, and as an example of the noble art of how not to do it, it is perhaps without a parallel." The conception of Hon. Abbott Lawrence, the donor, was exceptionally fine, and had his wishes in the matter been fulfilled the history of the engineering department of Lawrence Scientific School might have been very different. The following extracts from his letter of donation leave no doubt as to his personal views and wishes. He desired it to be "a school for

the purpose of teaching the practical sciences." There existed a "pressing want of an increased number of men educated in the practical sciences" or in "the practical applications of science." He desired the school to "educate our engineers, our miners, machinists, and mechanics." He further says: "I have thought that the three great branches to which a scientific education is to be applied amongst us are, first, engineering; second, mining, in its extended sense, including metallurgy; third, the invention and manufacture of machinery."

In 1849 Prof. Henry L. Eustis, second lieutenant of engineers, was appointed professor of engineering, and gave for some years very excellent instruction, and the failure of the school to live up to the wishes of Mr. Lawrence was in no way due to Prof. Eustis. The money was devoted to various other branches, and after his death no professor was appointed, and Harvard, in failing to live up to the letter of the bequest, forfeited an opportunity of having one of the most successful engineering departments of this country.

In spite of lack of funds and demands in other directions, the engineering courses had been established, and the first class of four was graduated in 1853. For a few years the school prospered, but in 1859 the decline began. Prof. Eustis went to war and returned much out of health and unable to fill the position. He died in 1885, and the engineering department disappeared for some time. Finally, under the guidance of Prof. W. S. Chaplin, followed by Prof. N. S. Shaler, as dean of the scientific schools, and Prof. I. N. Hollis, now professor of engineering, the department is coming to the front again, and Harvard may, even at this late day, partially redeem the unfortunate mistake made in disregarding the wishes of Mr. Lawrence.

In 1847 what is now Sheffield Scientific School of Yale University followed, but did little before 1852, and then was forced to economize in every way until 1859, when Mr. Joseph E. Sheffield reorganized the school. As an engineering school it did not get well under way before 1861, but the possibilities of this progress were brought about by earlier efforts, and much credit is due the institution for having maintained an existence until Mr. Sheffield's interest was secured in its behalf.

By a bequest from Mr. Abiel Chandler, the Chandler School of Science and the Arts was founded in 1851 in connection with Dartmouth College for "a permanent department of instruction in the practical and useful arts of life," under which head Mr. Chandler mentioned particularly mechanical engineering, civil en-

gineering, carpentry, masonry, architecture, drawing and modern languages, "together with bookkeeping and such other branches of knowledge as may best qualify young persons for active life."

Located also at Dartmouth College is the Thayer School of Civil Engineering, founded by Brig. Gen. Sylvanus Thayer, U. S. A., who was graduated in 1807 from Dartmouth and founded the Thayer School in 1867.

To Michigan belongs the honor of starting the first engineering school on other than private donations, and upon an equal footing with the other departments of the university. This was done in 1852 at the State University, and the first degrees of civil engineer were granted eight years later—1860. Michigan may well claim the distinction of founding the second strong engineering school in the United States, and this in the face of the poor and unsettled condition of the state prior to 1860.

No other institution giving engineering courses appeared until Brooklyn Polytechnic began graduating students in 1866, and this was soon followed by the Columbia College School of Mines, which was the first school of mines organized in America, although Michigan graduated a class the same year, 1867, and the Massachusetts Institute of Technology followed a year later.

To Prof. Thomas Eggleston belongs the honor of being the pioneer in organizing a school of mines. His plans for Columbia were made in 1863 and he was appointed professor in 1864. In speaking of the School of Mines at Columbia, the writer in the *Engineering News* says: "It needs only to add a course in mechanical engineering and the school will cover as broad a field as any other, and a broader than most." The course in mechanical engineering has now been added, and the School of Applied Science is in excellent condition.

The next institutions to present graduates were the Massachusetts Institute of Technology and Washington and Lee University, in Virginia, both of which graduated classes in 1868. From its organization the Institute of Technology was recognized as a remarkably strong institution, and it is still looked upon as a leader among engineering schools. Much of the success in founding this institution is due to Prof. Wm. B. Rogers. The organization meeting was held on January 11, 1861, and the act of incorporation gave the institute and the Boston Society of Natural History the site occupied by the buildings, two-thirds for the institute and the other third to the Society of Natural History.

Owing to the War of the Rebellion the school was not started until 1864, and meantime the Land Grant Bill—to be discussed

later—had been passed, and the Massachusetts Institute of Technology received a portion of the aid from this act. A class of thirteen was graduated in 1868. The first catalogue showed a list of seventy-two students, nearly all from the field that should have been covered by Lawrence Scientific School had that institution but taken advantage of its opportunities. The six courses originally outlined by Prof. Rogers have formed the basis of instruction, although others have been added from time to time. The institution has been most prosperous, and has proved a credit not only to Boston and Massachusetts, but to the country.

Since 1862 a large number of institutions having engineering departments have been organized, many of which resulted from the Land Grant Bill. Between 1865 and 1870 as many as eighteen were founded.

Stevens Institute, organized in 1871, has the distinction of giving instruction in mechanical engineering only, and of conferring but one degree, that of mechanical engineer.

Probably no other single act has done more to advance the possibilities of engineering education than the bill introduced into Congress by Hon. Justin Morrill, of Vermont, and commonly known as the Land Grant Bill. The original bill, introduced in 1858, was vetoed by President Buchanan, but in 1862 Senator Morrill again presented the bill, and on July 2d President Lincoln's signature made the bill a law.

Times were hard; the country was in a state of confusion and uncertainty; the interpretation of this law as passed was different in various states, and many sad mistakes were made during the history of the founding of these institutions. The conception was in itself wonderful, and, in spite of many serious mistakes on the part of the different states, a new era was opened to engineering education by the passage of the bill. The conditions of the law were that for each senator and representative in Congress the state should receive 30,000 acres of public lands, open for sale at $1.25 per acre, or instead each state was to receive scrip to be sold for the benefit of the state. For various reasons—misunderstanding of the law, a feeling of impatience or uncertainty, trickery or bad management—nearly all of the states failed to realize the full $1.25 per acre, and the majority received but a very small portion of this amount, one state receiving as little as 41 cents per acre. One state stands as a marked exception, viz., New York. Through the wisdom and caution of Mr. Ezra Cornell the investment was made to realize between $6 and $7 per acre on all but a small portion, which had been sold before Mr. Cornell secured control at

53 cents per acre. The result was that New York state received 42 per cent. of the amount realized from the total grant from her share of scrip, which was only about 10 per cent. of the total. The benefits resulting from the wisdom of Mr. Cornell have been most apparent in the progress of the excellent institution bearing his name. Nine states only succeeded in securing as much as the $1.25 per acre, and of these Tennessee received the least, $1.34½. The nine states to invest to good advantage were Tennessee, Wisconsin, Florida, Michigan, Iowa, Minnesota, California, Kansas and New York, the last three receiving more than $5 each per acre. These nine states received for 2,459,920 acres the sum of $10,633,-860, while the remaining twenty-nine received for 7,117,920 acres only $5,232,512. Considering this most unfortunate start, the positions occupied by the various state institutions at the present day are most flattering, as each state has since endeavored to live up to the letter of the law, and has made up the initial loss to a certain extent by liberal appropriations from time to time. The clause of especial interest in the Morrill act refers to the use of the funds derived from the proposed sale of lands, and states that the income should be appropriated "to the endowment, support and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and other mechanic arts in such manner as the legislatures of the states may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

The states accepted the responsibility and each state established its institution. In most states one institution only, including the courses in agriculture and the mechanic arts, was established, but Massachusetts made an exception, granting to the Institute of Technology, which was then coming to the front, a portion of the fund for its technical departments, the remainder going to establish the Agricultural College at Amherst. In a few states the fund was directed toward the development of the necessary departments in institutions already established. Thus came into existence a large number of colleges, the majority of which were to advance the interests of engineering education and many of which were destined to become leaders among the numerous universities of learning of the present day.

From time to time since the advent of these institutions, institutions founded by private funds have been organized, until to-day the opportunities for study in the varied lines of engineering are

so numerous and of such excellent quality as far to surpass the wildest dreams of the early promoters of such education. Not alone are there modern technical institutions where these various branches form the principal courses of study, but the old conservative universities have opened their doors and are striving to establish departments of engineering that shall rival those of the leading technical institutions.

The following statistics, secured directly from the institutions, serve to emphasize the wonderful progress that has been made. Although the list, of necessity, is incomplete, the general deductions are not seriously affected. Definite information was received from about 85 per cent. of the institutions giving technical instruction, and of the 15 per cent. from which no replies were received a few only could furnish information of material value in these deductions.

Many of the statistics for the civil, mechanical and mining departments prior to 1890 were taken from articles published in the *Engineering News* for 1892, thus saving much annoyance to the institutions that kindly filled the remaining blanks.

No attempt has been made to supply the desired data from the catalogues of the colleges from which no replies have been received. While in some cases this might be done to advantage, yet in general the results would be far too inaccurate to add value to these records.

Considering the courses offered, the returns show that at the close of the nineteenth century about 70 per cent. of the institutions considered offer a course in civil engineering, 64 per cent. offer mechanical engineering, while electrical engineering follows closely, being offered by nearly 60 per cent. Mining engineering is the only other course given by any large number of institutions, some 34 per cent. reporting such a course.

Architectural departments are listed from about 17 per cent. of the institutions, and it is interesting to note that fully half of the architectural courses were established within the last ten years of the century. Naval architecture has but recently entered the field, but three institutions reporting courses, Cornell University having established a course in 1890, the Massachusetts Institute of Technology in 1895 and the University of Michigan in 1900. Courses in chemical and sanitary engineering seem also to be limited in number, but six institutions reporting courses in the former and four only in the latter.

It is of interest to note the increase in the total number of graduates of the eighty colleges represented for the last twenty years of the century. The total for 1880 is lower than for some

years previous and the increase from 1880 to 1885 should perhaps be modified. The eighty colleges considered graduated from engineering courses:

	No.	Increase.	Per cent. Increase.
In 1880	148	...	...
In 1885	269	121	82
In 1890	618	349	130
In 1895	1,076	458	74
In 1900	1,217	141	13

The accompanying diagram shows the number of graduates from each department for the forty years from 1860 to the close of the college year of 1900, together with the fluctuations from year to year. Owing to the fact that among the few institutions from which no replies were received are one or two that graduated several civil engineers in the early sixties, the curves shown are somewhat lower than they should actually be for the first five or ten years. This, of course, may be said to be true of the actual figures for each year, but the percentage of error is very small after the first few years, and the curves show without perceptible error the relative growth of the different departments.

Perhaps the first point of interest in the diagram is the decrease in the number of graduates in the late seventies, which is accounted for by the panic of '73, the reduced number to enter the years of the financial depression causing the small number to graduate four years later. After recovering from this depression the number of graduates in mechanical engineering increased rapidly, with occasional minor fluctuations, until affected by the depression in the financial market of '92-'93.

From about '83 to '90 civil engineering had a prosperous growth, but from '90 to '95 a serious falling off in the number of graduates is observed. Ninety-six saw a decided improvement, which was necessarily cut short by the results of the hard times four years previous.

The number of graduates in electrical engineering increased from the first with remarkable rapidity until the natural falling off in '96-'97. The growth in mining engineering has been small from the beginning, but the demand for the past ten years seems to be stimulating an advance of this department.

The closing decade of the century presents some very interesting statistics, as noted below. In Table I is given the number of

classified students in engineering courses* in 1889-90 and in 1899-1900 in the eighty colleges from which returns were received.

TABLE I.

	1889-1890.	1899-1900.	Increase.	Per cent. Increase.
C. E.	1,647	2,432	785	48.0
M. E.	1,345	2,935	1,590	118.0
Mn. E.	599	1,441	842	140.0
E. E.	855	1,960	1,105	129.0
S. E.	7	16	9	13.0
Ch. E.	21	16	5	24.0
A.	268	299	31	11.5
N. A.	....	51	51	...
Totals	4,742	9,150	4,408	93.0

These figures do not in most cases include the first-year men, as in but few institutions are the courses determined before the second year.

In like manner Table II presents the number graduated in engineering courses in 1890 and in 1900 from the same eighty colleges:

TABLE II.

	1890.	1900.	Increase.	Per cent. Increase.
C. E.	265	287	22	8
M. E.	219	418	199	91
Mn. E.	25	139	114	456
E. E.	66	283	217	329
S. E.	....	4	4	...
Ch. E.	....	15	15	...
A.	43	62	19	44
N. A.	....	9	9	...
Totals	618	1,217	599	97

The percentages both in Tables I and II show, for the most part, very satisfactory increases. The increase in the number of graduates in mining engineering during the decade is certainly surprising. Although the increase in electrical engineering is very large, the result is not beyond expectations, as electrical engineering was in its infancy in 1890. Especial attention should be directed to the percentages of increase shown in the total attendance and total number of graduates in the engineering branches, Table I showing

*In the tables that follow, C. E. represents civil engineering; M. E., mechanical engineering; Mn. E., mining engineering; E. E., electrical engineering; S. E., sanitary engineering; Ch. E., chemical engineering; A., architecture; N. A., naval architecture.

the percentage of increase in attendance for the decade to be 93 and Table II that for increase in graduates 97, results which compare very favorably.

It is of interest to note the proportion of graduates to undergraduates, both in 1890 and 1900, as shown by Table III.

TABLE III.

PERCENTAGES OF GRADUATES TO UNDERGRADUATES.

	Per Cent. C. E.	Per Cent. M. E.	Per Cent. Mn. E.	Per Cent. E. E.	Per Cent. S. E.	Per Cent. Ch. E.	Per Cent. A.	Per Cent. N. A.	Per Cent. Total.
1890	16	16	4.2	7.7	..	..	16	..	13
1900	12	14	9.6	14.0	25	94	21	18	13

Glancing at the columns marked totals, it is seen that the ratio of the total number of graduates to the total number of undergraduates in the courses considered in the eighty institutions for 1890 and 1900 is exactly the same, the number of graduates being 13 per cent. of the number of undergraduates. Considering that the figures given for undergraduates are in most cases from three classes and the number graduating from one, this would indicate that the percentage of those taking these courses to graduate is about 39. This figure would be somewhat reduced were the first-year men considered, as the proportion to drop out during the first year is greater than during succeeding years.

It is hardly necessary to emphasize the fact that during this most healthy growth the standards of the various institutions have been constantly raised. This condition would naturally follow the general progress of the country as a whole, as well as the progress in engineering education.

Passing through the period when text-books were few, instructors poorly trained, illustrative apparatus and opportunities for research almost unknown, the engineering institutions awoke to find themselves among the leaders, with books of reference and text-books prepared by the best authorities; their instructors men of culture, experience and technical education; apparatus of the best, and, finally, engineering laboratories equipped for research work and practical illustration of the important principles and facts of engineering.

Of recent developments in connection with the advance of engineering education, the engineering laboratory is probably the most important. Such laboratories were proposed by Prof. W. B. Rogers about 1861, and in 1874 a steam engineering laboratory was established at the Massachusetts Institute of Technology. Prof. Channing Whitaker was placed in charge of this laboratory,

which was probably the first ever established. The influence of such laboratories has been very great, until to-day no institution of recognized standing in engineering can maintain a high position without well-equipped laboratories, as they are of the greatest importance as factors in instruction and training.

The development of some institutions to-day is such that they not only carry on their regular courses of instruction during the college year, but summer courses in the field, shop or mine are conducted, to give the student what practical experience is possible during his course of training. The regular recitations, lectures and laboratory work are supplemented by addresses by active men of experience and reputation, and by visits to manufacturing establishments and other places of interest for observation of the practical working out of the principles and methods of the classroom, together with the necessary modifications and changes to be made in formulas when applied to practice.

In addition to the regular undergraduate courses, some institutions are offering graduate courses in engineering, leading to the master's degree, and in some cases to the doctor's degree. Although the number of students pursuing graduate courses in technical lines is small, yet Table IV is not without interest, showing as it does the number of graduate students in engineering courses in 1889-90 and in 1899-1900 in the eighty colleges previously considered:

TABLE IV.

	1889-1890.	1899-1900.	Increase.	Per cent. Increase.
C. E.	32	45	13	41
M. E.	21	49	28	133
Mn. E.	17	35	18	106
E. E.	19	27	8	42
S. E.	..	..	..	..
Ch. E.	1	..	—1	—100
A.	..	2	2	..
N. A.	..	..	..	..
Totals	90	158	68	76

The sums spent annually upon the engineering institutions of this country are almost fabulous, yet the results seem to warrant such expenditure, for, judging from the past, much of the progress and welfare of the nation depends upon the successful education and training of its engineers.

An attempt was made to ascertain not only the annual tuition, but also the other fees that are charged to the student, and the annual cost to the institution per year per capita for running its

technical department. It was intended to determine as closely as possible the excess in the cost to the institution for each student over the amount received. Several difficulties have arisen in this effort, the chief one being that ten institutions only gave any figures regarding the cost per year per capita. The annual fees were found to be so variable that little of definite form could be obtained, but it seems that in most cases the fees are for materials used, or for breakage, and, with the possible exception of matriculation or graduation fees, the income and output would about balance. The ten institutions that reported upon the approximate cost per year per capita for running their engineering departments are listed below:*

COLLEGE.	Charge for Tuition.	Approx. Cost per Year per Capita.	Cost to Institution above Tuition.
Alabama Polytechnic Institute...	(R.) Free, (N.R.) $20	$25	(R.) $25, (N.R.) $5
Case School of Applied Science..	$100	350	$250
Colorado School of Mines.........	(R.) Free, (N.R.) $100	200	(R.) $200, (N.R.) $100
Kansas Agricultural College.....	Free	39	$39
Mass. Institute of Technology...	$200	335	135
Michigan College of Mines........	(R.) $25, (N.R.) $150	385	(R.) $360, (N.R.) $235
Montana Agricultural College...	$12	150	$138
Rose Polytechnic Institute........	75	350	275
Stevens Institute......................	(R.) $100, (N.R.) $225	275	(R.) $175, (N.R.) $50
Worcester Polytechnic Institute..	$150	290	$140

Of the sixty-six institutions reporting upon the amount of tuition, sixteen offer free tuition and seven others offer free tuition to residents but charge tuition to non-residents. In all thirteen of the sixty-six seem to discriminate between residents and non-residents.

About 20 per cent. of the institutions reporting charge at least $100, but not over $150, while only three receive more than $150, and each of these makes its tuition $200.† One institution, charging $100 for residents, advances its tuition to $225 for non-residents.

The development of the various departments of engineering has been closely connected with similar progress in the practical application of these branches in the engineering world. Which may be considered the result of the other is not definitely determined; that is, did the demand necessitate education in these special lines, or did the development of certain special features in the educational institutions lead to the discoveries and application of the new methods and processes? The two conditions are closely

*(R) indicates resident and (N. R.) non-resident.

†One institution has recently advanced its tuition to $250.

related, and it is probable that the one stimulated the other. In this connection Prof. F. R. Hutton has said: "It has been well pointed out that the industrial development of a country is progressive, and begins with a call, first, for the hunter and trapper; secondly, for the pioneer settler; thirdly, for the mining engineer and agriculturist; fourthly, for the civil engineer and specialist in transportation problems, and lastly, for the engineer who will develop manufacturing. It is presumed that this historical trend explains the development, throughout New England and the Eastern and Middle States, of the colleges and courses in mechanical and electrical engineering. It explains in part why one course catches up to, transcends and falls behind another, in spite of the best reputation, equipment and facilities of that other."

The recognized standing of the graduates of these engineering schools to-day is, without question, a great change for the better having taken place in the past twenty years, and to-day the technically educated man of ability is looked upon with favor by the officials of large corporations, and his position is practically assured. The very fact that he has to apply himself more closely and finds his course of training more rigorous than in the older courses for corresponding training in law, medicine or similar professions, has tended to place the work of the engineer upon a basis not only commanding respect, but making the profession a learned profession in the highest sense, for to-day no other department requires more work or a better quality of work of its students than is required of the student of engineering.

Possibly the most unfavorable criticism that can be offered concerning the present engineering school is its tendency to become too technical, in some cases not devoting the attention necessary for developing the man, as a man, in addition to developing him as a machine. The limited time at command and the extensive ground that must be covered make the avoidance of this tendency a serious question. The cultivation of those qualities which make "the man" is of the greatest importance, and should not be lost sight of in the endeavor to secure what appears to the average young man of immature development and restless ambition as the so-called "bread and butter" education. Unfortunately, there is a tendency on the part of many students in technical institutions to look upon general or culture subjects with disfavor, or at least with the thought that they are of no direct value in earning a living, and hence would better be left out of the course, or, if taken, should be regarded as secondary.

It is Pope who says:

"A little knowledge is a dangerous thing.
Drink deep or taste not the Pierian spring,
There shallow draughts intoxicate the brain,
And drinking deeply sobers it again."

The condition above referred to can be changed only by degrees. The experience of former generations will tend to correct this fault to some extent in the future, but the opportunity for direct improvement lies within the institutions themselves. Some institutions are at present fairly rigid in regard to requirements in courses of a purely general character, but with many these requirements are too easily modified, while with some, if not all, the tendency to specialize is so strong that the greater portion of the culture subjects have been forced from the curriculum.

The scope of this paper and the limited time at command will not permit a complete discussion of the correctness of courses as now arranged; the lack of training in English; the proper requirements for admission; the tendency to specialize in some institutions; the mistake, according to the writer's view, of granting the professional degree upon graduation, and other similar points which are deserving of careful study.

The results of the excellent work of these progressive institutions are readily seen in the great engineering feats of the past few years, in the growth and prosperity due to such achievements, in the accomplishments due to engineering training in our recent war, and one need only trace these results to their sources to be convinced that the engineering school of to-day is a powerful factor in a nation's civilization and development, as well as in the general progress of the world. For the men who are achieving these results are men whose earnestness of purpose and appreciation and respect for the laws governing existing conditions have been guided and strengthened by these institutions—institutions whose aim has been to develop serious thought, power to weigh facts, ability to probe the reasons and laws producing given conditions, a true respect for the opinions and judgment of others—a comprehension of facts and conditions as they exist to-day, and the power so to modify, improve or take advantage of these facts that new and better conditions and opportunities shall be open to him who enters the world to-morrow.

Herbert Spencer, in referring to the schools of England, might have referred with equal force to the schools of the United States when he wrote: "That which our school courses leave almost entirely out we thus find to be that which most nearly concerns the business of life. All our industries would cease were it not for that

information which men begin to acquire as they best may after their education is said to be finished. And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed." It is this very field that the engineering schools have filled and are filling so acceptably to-day. Their wonderful growth has exceeded all expectation, and the quality of their work has made for them a position surpassed in importance by no other educational development of the past century. No finer tribute to the work of the engineering school can be paid than the following from an address delivered by that able and noted educator, Gen. Francis A. Walker, at McGill University in 1893.

"The growth of scientific and technical schools on this continent during the past thirty years has savored of the marvelous."

"The notion that scientific work was something essentially less fine and high and noble than the pursuit of rhetoric and philosophy, Latin and Greek, was deeply seated in the minds of the leading educators of America a generation ago. And it has not even yet wholly yielded to the demonstration offered by the admirable effects of the new education in training young men to be as modest and earnest, as sincere, manly and pure, as broad and appreciative, as were the best products of the classical culture, and withal, more exact and resolute and strong. We can hardly hope to see that inveterate prepossession altogether disappear from the minds of those who have entertained it. Probably these good men will have to be buried with more or less of their prejudices still wrapped about them; but from the new generation scientific and technical studies will encounter no such obstruction, will suffer no such disparagement."

"The practical uselessness, for any immediate purpose, of a given subject of study may be no reason why it should not be pursued; but, on the other hand, the high immediate usefulness of a subject of study furnishes no ground from which the educator of loftiest aims and purest ideals should regard it with contempt or distrust. In either case, the question of real import is in what spirit the study is pursued."

"I know the scientific men of America well, and I entertain a profound conviction that in sincerity, simplicity, fidelity, and generosity of character, in nobility of aims and earnestness of effort, in everything which should be involved in the conception of disinterestedness, they are surpassed, if indeed they are approached, by no other body of men."

REDUCTION OF GRADE ON RAILROADS.

By C. D. Purdon, Member of the Engineers' Club of St. Louis.

[Read before the Club, May 6, 1903.*]

Since railroads passed the experimental and entered the commercial stage there has been a constant effort in all departments to devise means for operating with greater economy.

While much has been done to this end outside of the railroad proper, such as the production of rails, etc., by cheaper methods, what I refer to particularly is the actual moving of freight over the tracks; and one of the most important items of the cost of this service is the size of the train which can be hauled.

Probably one of the first steps toward cheaper service was the improvement of freight cars. Many of us can recollect when a freight car carried a paying load little, if any, greater than the weight of the car itself.

To-day we have, for heavy freight, cars carrying a load of 100,000 pounds, while the car itself weighs about 40,000 pounds.

Our locomotives have increased from the ancient style, with a weight of some 18,000 or 20,000 pounds on each of the driving axles (of which there were only two), to what may be considered as the present average freight engine of four driving axles, each with a weight of about 40,000 pounds.

It is true that there are in service such monsters as the Pittsburg, Bessemer and Lake Erie, with over 56,000 pounds on a driving axle, but such are exceptional.

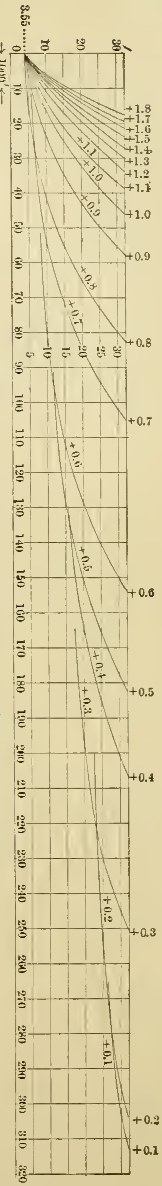
Such engines and cars have required the practical rebuilding of all our railroads, changing from 52 or 56-pound steel, without ballast, and Howe truss bridge, to rails of 75 pounds or over, 10 or 12 inches of ballast and heavy steel bridges with massive masonry substructures.

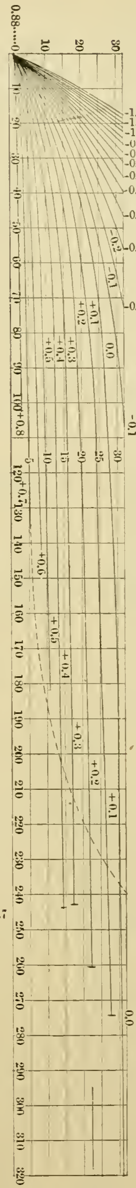
Statistics show that, with all the immense sums of money expended in these improvements, the cost of carrying freight has steadily decreased, thus proving the economy.

While it would be rash to prophesy that the size of engines and cars has reached a limit, it is certain that the development has reached a very high stage, and advances upon these lines in the future cannot possibly approach the developments already made.

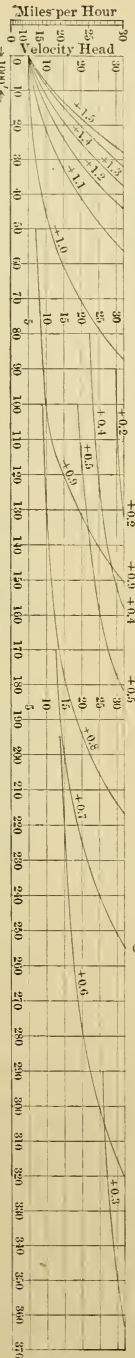
With a view to further economy in train movement, the most promising field at present appears to be the reduction of the grades.

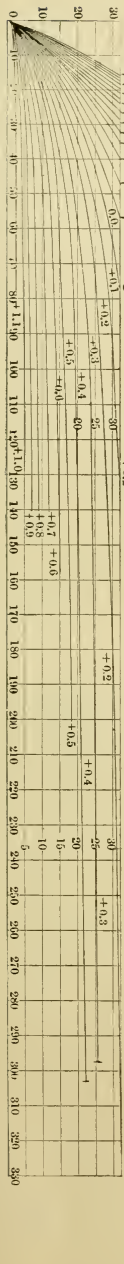
*Manuscript received June 6, 1903.—Secretary, Ass'n of Eng. Socs.



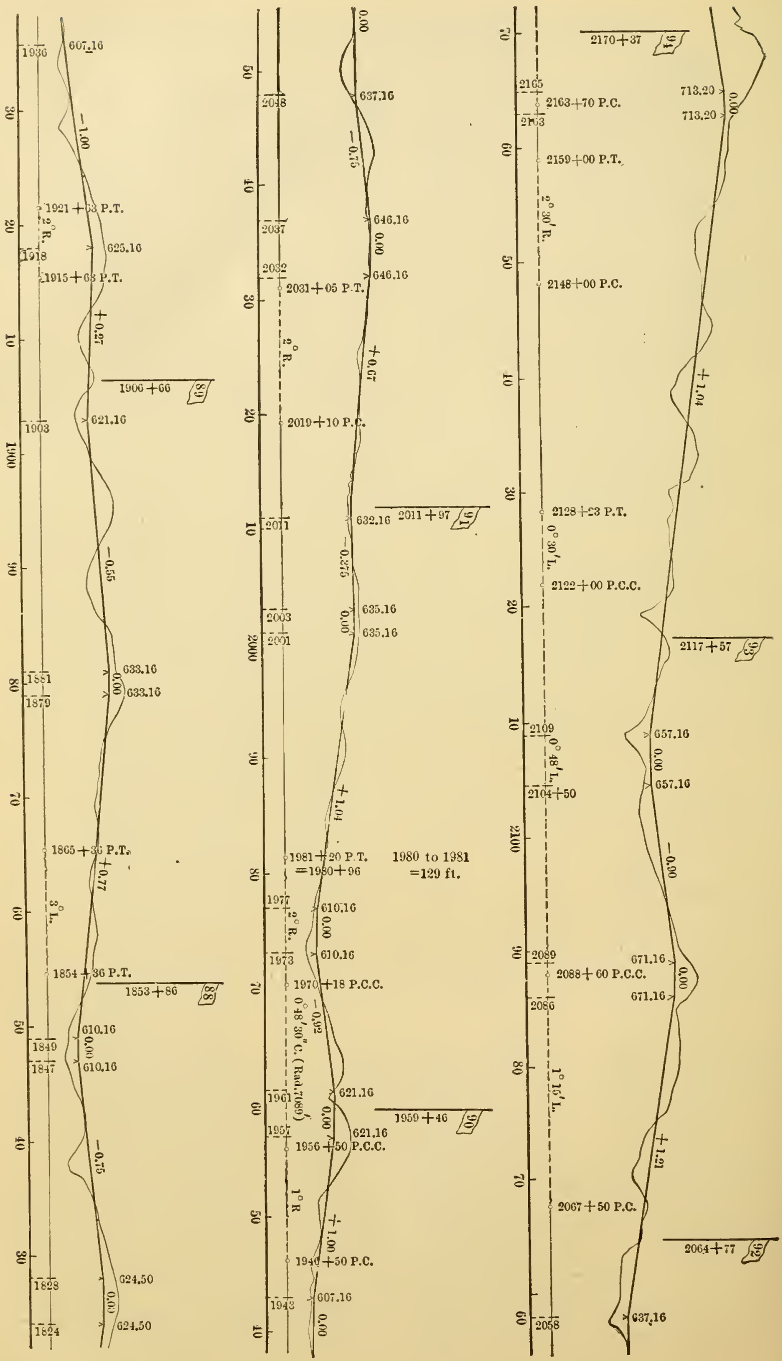


Velocity Heads for a train whose maximum speed on a 0.7% grade is 12 miles per hour
upper diagram shows retarding; lower, accelerating, grades.





Velocity Heads for a train whose maximum speed is 12 miles per hour on a 1% grade
upper diagram shows retarding; lower, accelerating, grades.


1936
607.16
−1.00
1921+63 P.T.
2° R.
625.16
1918
1915+63 P.T.
+0.27
1906+66
89
621.16
1903
−0.55
1881
633.16
0.00
633.16
1879
1865+36 P.T.
+0.77
3° L.
1854+36 P.T.
1853+86
88
610.16
0.00
610.16
1849
1847
−0.75
624.50
0.00
624.50
1828
1824
0.00
2048
637.16
−0.75
2037
646.16
0.00
2032
646.16
2031+05 P.T.
2° R.
+0.67
2019+10 P.C.
2011+97
91
632.16
2011
−0.275
635.16
0.00
635.16
2003
2001
+1.04
1981+20 P.T.
=1980+96
1980 to 1981
=129 ft.
1977
610.16
0.00
610.16
2° R.
1973
1970+18 P.C.C.
0° 48′ 30″ C. (Rad.7089′)
−0.92
621.16
1961
1959+46
90
0.00
621.16
1957
1956+50 P.C.C.
1° R
+1.00
1940+50 P.C.
607.16
0.00
1943
2170+37
94
2165
2163+70 P.C.
2163
713.20
0.00
713.20
2159+00 P.T.
2° 30′ R.
2148+00 P.C.
+1.04
2128+23 P.T.
0° 30′ L.
2122+00 P.C.C.
2117+57
93
2109
657.16
0.00
657.16
0° 48′ L.
2104+50
−0.90
2089
671.16
2088+60 P.C.C.
0.00
671.16
2086
1° 15′ L.
+1.21
2067+50 P.C.
2064+77
92
637.16
2058

and as many of our principal railroads are already engaged in this work, and more are considering it, a short paper on the questions that arise upon the subject may be of interest.

It would of course appear, at first, that to take the profile and a straight edge and draw lines reducing the grades to those desired by cutting off the tops of the hills and raising the sags would be quite simple; and it would; but whether it would be the proper method is, at any rate, open to argument.

It has always been known that to "take a run at the hill" will help a train to surmount it; or, to speak more scientifically, that a train approaching a hill will ascend more easily the more speed it has attained before reaching the up-grade. This is taken advantage of by every train, and trains are made up on the basis of what the engine can get over the road with, ascertained by experience, and not from any calculations based on the grades shown by the profile.

The length of an adverse grade and the character and rates of the grades preceding it are more important than the actual rate per cent. of the grade itself, and it can easily be understood that a very long adverse grade, of a rate much less than the maximum, could limit the train load more than short grades of the maximum rate.

So that, to reduce grades over a division to the above mentioned ruling grade, perhaps 2-10 or 3-10 less than the maximum, would not enable an engine to haul an additional car.

Bearing this in mind, and also the fact that the train load will be what experience shows can be moved, it seems reasonable in grade reductions to take account of the velocity with which a train reaches an adverse grade, calculate how far up that adverse grade the stored-up energy and capacity of the engine will take the train, and begin reduction at that point instead of at the foot of the hill.

It does not follow that the grade showing the greatest rate per cent. is the ruling grade of a division or the grade that limits the weight of a train.

To get the best results for the least expenditure, therefore, it is necessary to make a study of each freight division and ascertain what effect each particular grade has upon a train, and then, by reducing the ruling or limiting grades, establish a virtual or equivalent grade for a division, which will be the limiting grade for trains, even if many of the grades show a greater rate per cent.

An objection may be made to this method on account of the possibility of a train having to stop from any cause on a grade

exceeding the virtual, and so be unable to start again without doubling the hill, but it is very questionable if this possibility will justify the very much greater expense of reducing all the grades, even if a train does get into trouble occasionally.

Many engineers have made rules for using the momentum of a train in an intelligent manner, and this paper is intended as a description of these rules and the method of use.

So far as the writer knows, the late Mr. A. M. Wellington was the first engineer to formulate rules establishing virtual grades, and he did establish, from brake tests and otherwise, the resistance of moving trains. His information has been greatly extended by others, notably by the engineers of the Southern Pacific, and, while many engineers differ in their methods, they reach practically the same results.

Suppose, for example, that a freight division has grades exceeding 1 per cent., and that it is desired to reduce to an equivalent 1 per cent. We must first study the profile for the effect each grade has upon the grade joining it and ascertain what momentum a train has at the beginning and end of each particular grade, and whether the momentum will enable the train to pass over the hill, or, if not, to what point on the hill it will assist, which point will be the place to begin reduction.

Certain points have been ascertained by Wellington, the Southern Pacific engineers and others. It is found that at each rate of speed the train has stored up energy enough to lift it a certain height, or take it a certain distance up an uprising grade if the engine only overcomes friction. This property is called the velocity head. It is also found what acceleration of speed or increase of velocity head is attained on a descending grade, the tractive power of an engine at various speeds and the resistance of the train in pounds per ton due to speed and to grade are also established.

Each engineer will choose his data for himself, but for sake of example the following will be taken:

Virtual ruling grade to be 1 per cent.

A stop to be made at each station.

A train to leave the yard limits at a speed of 5 miles per hour, or with a velocity head of 0.88 feet.

Weight of train to be such that the engine can maintain a speed of 12 miles per hour on a continuous ascending grade of 1 per cent.

Maximum speed of train to be 30 miles per hour, or velocity head 31.95 feet.

Minimum speed at top of hill, 10 miles per hour or velocity head of 3.55 feet.

We then make a table similar to Table 1.

The first column contains the speed in miles per hour.

The second column contains the corresponding velocity head, which will be used instead of the speed for convenience in calculating.

The third column contains the differences of the velocity heads in column 2.

The fourth column contains the tractive power of the engine in pounds per ton of train at various speeds, on the basis of an assumed power of 25 pounds per ton on ascending 1 per cent. grade at 12 miles per hour, of which 20 pounds is required for the grade and 5 for the speed.

The fifth column contains the resistance in pounds per ton due to the speed.

The sixth column contains the difference between columns 4 and 5, or the excess tractive power of the engine.

The seventh column gives this excess tractive power changed to grade at the rate of 20 pounds for 1 per cent. grade, grade being + or —.

We then take any rate of grade, and the algebraic sum of the grade considered and the equivalent grade in column 7 divided into the difference of velocity heads in column 3 will give the distance traveled by the train in passing from one rate of speed to the next higher. These distances are shown in column 8 for a — 0.4 grade, and column 9 gives the successive addition of column 8.

Columns 10 and 11 contain the same figures for a + 0.4 grade. These two grades are given as an example. It is, of course, necessary to calculate the two columns for each particular grade, + or —, which may be required, but it will be generally sufficient to use even 10ths.

All descending grades and all ascending below the maximum are accelerating up to a certain point. A train on an ascending grade of 1 per cent. will gain speed till it reaches 12 miles per hour, but a train at any greater speed will lose on an ascending 1 per cent. until it falls to 12 miles per hour, so that even descending grades may become retarding above a certain speed.

Column 11 shows the point at which a + 0.4 grade ceases to accelerate and begins to retard.

A diagram similar to that attached is then platted from the velocity heads and sums of distances for each grade, giving para-

bolic curves, the directions of which change as they change from accelerating to retarding.

For convenience the diagram is made in two parts, accelerating and retarding. It will be noted that many of the grades appear on both parts of the diagram.

When this diagram is made the study of the profile is begun.

A profile of about 7 miles of road is attached for an example, showing one grade of 1.21 and another of 1.04, neither of which is compensated for curvature.

We will compensate for curvature as follows:

Curves of 2 degrees and under, 0.03 per degree.

Curves over 2 degrees and under 5 degrees, 0.04 per degree.

Curves of 5 degrees and over, 0.05 per degree.

Suppose the train at station 1848 with a velocity head of 0.88 feet, it encounters a descending grade of 0.75 per cent. 1900 feet long. Entering the diagram we find, at the intersection of 0.75 and 1900, a velocity head of 26.5 feet. Then, taking 200 feet of 0.0 grade, with a velocity head of 26.5 feet, we get 27 at the foot of the + 0.77 grade; this 0.77 grade is taken as 536 feet of 0.77, 1100 feet of 0.89 and 1364 feet of 0.77 on account of curvature, and we find by continuing the use of the diagram that the train has a velocity head of 15 feet at station 1879.

The continuation of these calculations is given in Table No. 3, the first and second columns giving profile stations, third column the length of the grade, fourth column the rate of grade compensated for curvature (adding the compensating rate to ascending and deducting it from descending grades), and the fifth column the velocity head at each change of grade for westbound trains.

The seventh and eighth columns give the corresponding figures for eastbound trains.

It will be seen that a train loaded for 12 miles per hour on a + 1 per cent. grade will arrive at the top of the 1.21 grade with a velocity head of 9.5 feet (over 16 miles per hour), and at the top of the much longer 1.04 grade with a velocity head of 5.2 feet (over 12 miles per hour).

So that to reduce these grades to actual 1 per cent. would not enable us to increase the train load.

Table No. 2 gives the calculations to make a diagram for a train loaded for a maximum speed of 12 miles per hour on a continuous ascending grade of 0.7 per cent., and a print of the diagram is attached.

In Table No. 3 the sixth column gives the velocity heads for a westbound train, and column 9 the velocity heads for an eastbound

train, over the same profile as used above, using a virtual maximum grade of 0.7 per cent.

This shows that a train loaded for a maximum speed of 12 miles per hour on an ascending grade of 0.7 per cent. will fall to 10 miles per hour 200 feet short of the top of the 1.21 per cent. hill, and 2050 feet before reaching the top of the 1.04 per cent. hill.

Thus, to reduce these grades to a virtual 0.7 per cent. would only require changing the tops of these two hills as shown in red lines upon the profile.

Practically the 1.21 hill would not require reduction, but these figures are given for illustration of the method.

Having studied the profile in one direction, it is then studied in the other, and possibly changes will occur which may modify the first set of figures.

It is not necessary to discuss the best way of doing the actual work of grading, further than to suggest that if a grade requires raising any considerable amount, it is best to build a new line adjoining to avoid interference with traffic, building as close as possible.

As many roads have their embankments made from borrowed material, any considerable raise will fill the borrow pits, so that no earthwork is saved by trying to utilize the old bank.

It is doubtful whether a new road should be built on the momentum principle. On an old road water tanks, stations and other stopping points are fairly well established, while on a new road they are not. It might be well, however, to try and make the grade at tops of hills always less than maximum.

The cost of the actual work of reduction is a matter of estimating, and after the estimated cost of reduction has been obtained it becomes a question of whether it will pay to reduce.

All depends on the volume of business and the cost per mile of running a train, taking only such items of cost as are affected by the size of the train—mainly fuel, wages and train supplies, probably about 35 cents.

By reducing the grades we will increase the size and consequently decrease the number of trains and also the train mileage; and an extreme case might be supposed where much development of location was required for the reduced grade, in which the train mileage was increased more by the length of line added than it was decreased by the less number of trains.

Also the volume of business might be such that freight could not be held long enough to make up the larger trains.

Taking the present number of trains, adding prospective in-

TABLE I.

Speed. Miles per Hour.	Velocity Head.	Difference of Velocity Heads.	Tractive Power of Engine.	Train Resistance.	Tractive Power—Resistance.	Equivalent Grade.	—0.4 Grade.		+0.4 Grade.	
							Distance.	Total Distance.	Distance.	Total Distance.
5	0.88		29.60	4.50	25.10	—1.25	0.31			
6	1.26	0.38	28.94	4.55	24.39	—1.22	0.23	0.52	0.52	
7	1.71	0.45	28.29	4.60	23.69	—1.18	0.29	0.52	0.66	1.18
8	2.24	0.53	27.63	4.65	22.98	—1.15	0.34	1.86	0.81	1.99
9	2.83	0.59	26.97	4.70	22.27	—1.11	0.39	1.25	0.96	2.95
10	3.55	0.72	26.31	4.80	21.51	—1.07	0.49	1.74	1.26	4.21
11	4.30	0.75	25.65	4.90	20.75	—1.03	0.52	2.26	1.41	5.62
12	5.11	0.81	25.00	5 00	20.00	—1.00	0.57	2.83	1.62	7.24
13	6.00	0.89	24.35	5.20	19.15	—0.95	0.65	3.48	1.80	9.04
14	6.96	0.96	23.68	5.50	18.18	—0.91	0.73	4.21	2.34	11.38
15	7.99	1.03	23.02	5.80	17.22	—0.86	0.81	5 02	2.86	14.24
16	9.09	1.10	22.37	6.00	16.37	—0.82	0.90	5.92	3.43	17.67
17	10.26	1.17	21.71	6.20	15.51	—0.77	1 00	6.92	4.33	22.00
18	11.50	1.24	21.05	6.50	14.55	—0.72	1.10	8.02	5.63	27.63
19	12.82	1.32	20.39	6.80	13.59	—0.68	1.22	9.24	7.66	35.29
20	14.20	1.38	19.73	7.10	12.63	—0.63	1.34	10.58	10.61	45.90
21	15.67	1.47	19.07	7.40	11.33	—0.56	1.50	12.08	24.50	70.40
22	17.19	1.52	18.42	7.80	10.62	—0.53	1.63	13.71	50.66	121.06
23	18.79	1.60	17.76	8.20	9.56	—0.48	1.82	15.53	80.00	201.06
24	20.46	1.67	17.24	8.50	8.74	—0.43	2.01	17.54	23.85	23.85
25	22.20	1.74	16.71	8.80	7.91	—0.39	2.20	19.74	15.82	39.67
26	24.00	1.80	16.18	9.00	7.18	—0.36	2.37	22.11	12.86	52.53
27	25.88	1.88	15.66	9.50	6.16	—0.31	2.64	24.75	9.89	62.42
28	27.83	1.95	15.13	10.00	5.13	—0.25	3.00	27.75	7.80	70 22
29	29.86	2.03	14.60	10.50	4.10	—0.20	3.38	31.13	6.76	76.98
30	31.95	2.09	14.08	11.00	3.08	—0.15	3.80	34.93	5.97	82.95

Data for speed of 12 miles on 1 per cent. grade.

TABLE II.

Tractive Power of Engine.	Train Resistance.	Tractive Power—Resistance.	Equivalent Grade.	—0.4 Grade.		+0.4 Grade.	
				Distance.	Total Distance.	Distance.	Total Distance.
22.5	4.50	18.00	—0.90				
22.0	4.55	17.45	—0.87	0 30		0.81	
21.5	4.60	16.90	—0.84	0.36	0.66	1.02	1.83
21.0	4.65	16.35	—0.82	0.43	1.09	1.26	3.09
20.5	4.70	15.80	—0.79	0.49	1.58	1.51	4.60
20.0	4.80	15.20	—0.76	0.62	2.20	2.00	6.60
19.5	4.90	14 60	—0.73	0 66	2.86	2.27	8.87
19.0	5.00	14.00	—0.70	0.73	3.59	2.70	11.57
18.5	5.20	13.30	—0.66	0.84	4.43	3 42	14.99
18.0	5.50	12.50	—0.62	0.94	5.37	4.36	19.35
17.5	5.80	11.70	—0.58	1.05	6.42	5.72	25.07
17.0	6.00	11.00	—0.55	1.15	7.57	7.33	32.40
16.5	6.20	10.30	—0.51	1.28	8.85	10.63	43.03
16.0	6.50	9.50	—0.47	1.42	10.27	17.71	60.74
15.5	6.80	8.70	—0.43	1.59	11 86	44.00	104.74
15.0	7.10	7.90	—0.39	1.74	13.60	138.00	242.74
14.5	7.40	7.10	—0.35	1.96	15.56	29.40	29.40
14.0	7.80	6.20	—0.31	2.14	17.70	16.66	46.06
13.5	8.20	5.30	—0.26	2.42	20.12	11.43	57.49
13.1	8.50	4.60	—0.23	2.65	22.77	9.82	67.31
12.7	8.80	3 90	—0.19	2.95	25 72	8.28	75.59
12.3	9.00	3.30	—0.16	3.21	28.93	7.50	83.09
11.9	9.50	2.40	—0.12	3.61	32.54	6.71	89.80
11.5	10.00	1.50	—0.07	4.15	36 69	5.90	95.70
11.1	10.50	0.60	—0.03	4.72	41.41	5.48	101.18
10.7	11.00	—0.30	+0.01	5.36	46.77	5.09	106.27

Data for speed of 12 miles on 0.7 per cent. grade.

crease of business (if advisable) and the length of the division, the number of trains required will be found by taking the inverse ratio of the increased train load to the present load. This gives the

TABLE III.

Sta. to Sta.		Length.	Westbound.			Eastbound.		
			Grade.	V. H. 1%.	V. H. 0.7.	Grade.	V. H. 1%.	V. H. 0.7.
1828	1847	1900	—0.75	26.5	23.0	+0.75	23.0	19.5
1847	1849	200	0.00	27.0	23.5	0.00	32.0	32.0
1849	1854+	536	+0.77	24.0	21.0	—0.77	32.0	32.0
1854+	1865+	1100	+0.89	18.0	14.5	—0.65	32.0	32.0
1865+	1879	1364	+0.77	15.0	10.0	—0.77	32.0	28.5
1879	1881	200	0.00	16.0	11.0	0.00	23.5	16.5
1881	1903	2200	—0.55	32.0	28.0	+0.55	23.0	16.0
1903	1915+	1263	+0.27	30.0	25.0	—0.27	30.0	23.0
1915+	1918	237	+0.33	29.5	24.5	—0.21	19.5	17.5
1918	1921+	363	—0.94	32.0	29.0	+1.06	18.5	16.5
1921+	1936	1437	—1.00	32.0	32.0	+1.00	20.5	19.0
1936	1943	700	0.00	32.0	32.0	0.00	32.0	32.0
1943	1946+	350	+1.00	29.0	28.5	—1.00	32.0	32.0
1946+	1957	1050	+1.03	21.0	19.0	—0.97	32.0	32.0
1957	1961	400	+0.03	22.0	19.5	+0.03	25.0	21.0
1961	1970+	918	—0.90	32.0	29.0	+0.95	24.0	20.5
1970+	1973	282	—0.86	32.0	31.5	+0.98	29.5	28.5
1973	1977	400	+0.06	32.0	31.0	+0.06	32.0	31.0
1977	1980+	396	+1.10	28.5	27.0	—0.98	32.0	32.0
1980+	2001	1980	+1.04	15.5	11.0	—1.04	32.0	32.0
2001	2003	200	0.00	16.5	12.0	0.00	29.5	29.5
2003	2011	806	—0.37	22.5	17.0	+0.37	29.5	29.5
2011	2019+	810	+0.67	20.0	14.5	—0.67	32.0	32.0
2019+	2032	1290	+0.73	16.5	10.0	—0.61	32.0	32.0
2032	2037	500	0.00	19.0	12.5	0.00	27.0	25.0
2037	2048	1100	—0.75	30.5	24.0	+0.75	26.0	24.5
2048	2058	1000	0.00	31.0	25.0	0.00	32.0	32.0
2058	2067+	950	+1.21	21.5	15.5	—1.21	32.0	32.0
2067+	2086	1850	+1.25	9.5	16.50	—1.17	32.0	32.0
2086	2089	300	+0.04	11.0	7.0	+0.04	22.0	20.5
2089	2104+	1550	—0.87	30.0	24.0	+0.93	21.0	20.0
2104+	2109	450	+0.03	30.5	24.5	+0.03	32.0	32.0
2109	2128+	1923	+1.07	17.0	9.5	—1.01	32.0	32.0
2128+	2148	1977	+1.05	9.0	14.50	—1.04	32.0	32.0
2148	2159	1100	+1.11	6.0		—0.97	19.0	26.0
2159	2163	400	+1.04	5.2		—1.04	9.0	8.0

number of train miles saved annually, which, taken at (say) 35 cents and capitalized, will show the amount on which the economy of operation will pay interest.

It may be found, when the volume of business is fairly well settled, that a different virtual grade can be used in one direction from that used in the other.

EARLY AND CURIOUS TYPES OF THE CANTILEVER BRIDGE IN NEW ENGLAND AND NEW BRUNSWICK.

By Alfred W. Parker, M.E.

[Read before the Boston Society of Civil Engineers, March 18, 1903.*]

Mr. President and Gentlemen:

A few months ago, during a business call at a store on Oliver street, Boston, reference was made to the fact that about forty years ago Fort Hill was standing, Oliver and High streets then running over the top, the crossing being about 50 feet above the present grade. The proprietor then produced the photograph which you see here (Fig. 1), showing Oliver street cut through the hill to the present grade, with High street at the old grade and a wooden combination cantilever and bowstring girder bridge spanning the chasm. On showing the photograph to your president and telling him some particulars about the building of this and other similar bridges, both wood and iron, previous to 1870, he seemed to think the matter interesting as a bit of curious bridge history, and invited me to tell the story here.

The bridge shown in Fig. 1 was built in 1868 by the Solid Lever Bridge Company, a Massachusetts corporation, incorporated July 6th of that year. It was contracted for by the Street Department of Boston before the days of the present method of having all city bridges designed in the city engineer's department; otherwise, a veto would probably have changed a bit of this history.

The corporation name well describes the lever portions of the structure, which were *solid,* being built of 12 x 3 inch, spruce deal laid flat one upon the other and pinned together by wooden trenails. The shore ends of the two levers were started simultaneously on opposite banks. Floor beams were framed between and loaded with stone for the counterweights, and the levers were then built upward and outward, each course of plank, as laid, being projected beyond the previous one till the ends of the completed levers met in mid span. An arch built up of the same material was then added, the top portion of the lever acting as the chord or bowstring of the arch.

The floor line was at the top of the levers, the banks being cut down to receive the shore ends.

The originator of this curious structure was a very skillful

*Manuscript received July 2, 1903.—Secretary, Ass'n of Eng. Socs.

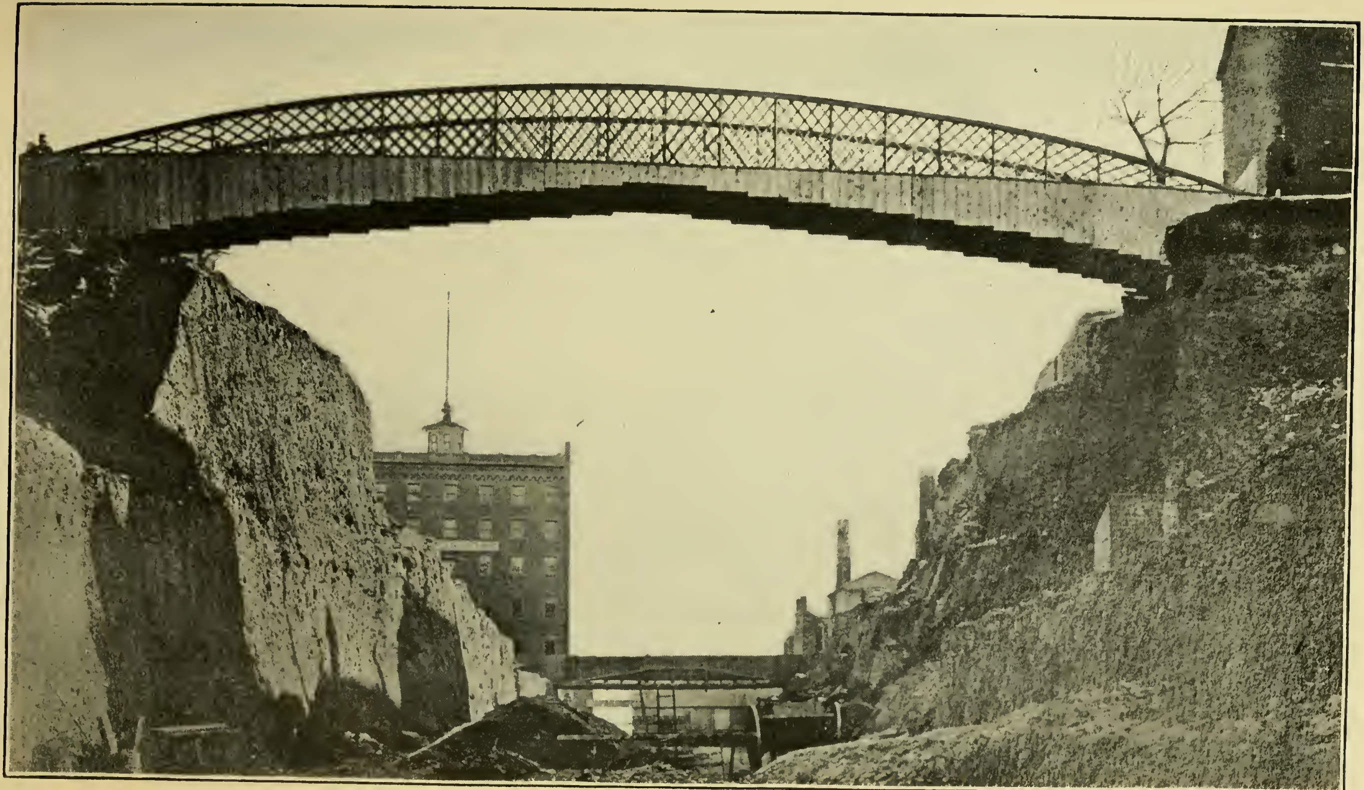


Fig. 1. High Street Bridge, over Oliver Street, Boston.

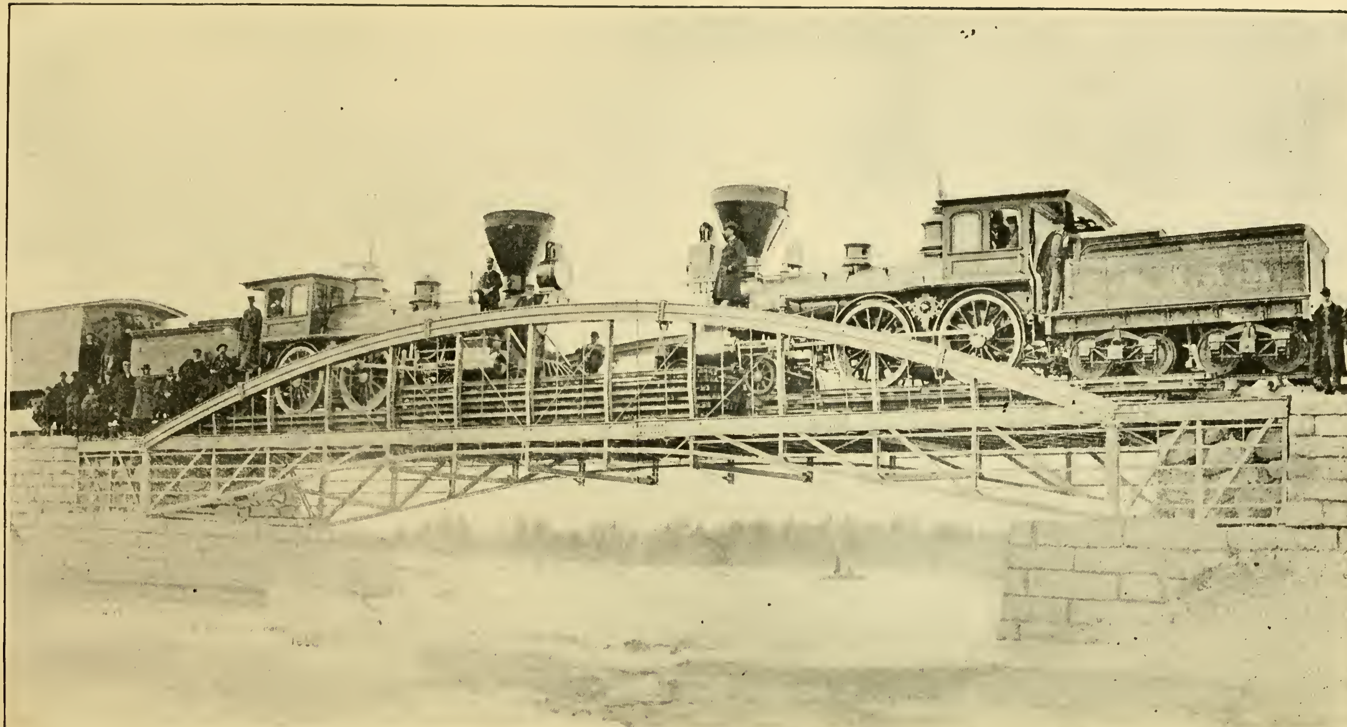


Fig. 2. Bridge over Olamon River, Maine.

carpenter and wooden bridge builder named Cottrell. He had built many wooden Howe-truss and lattice bridges, and became possessed with the idea of avoiding false work in swift rivers and deep chasms by building from the shore outward through space to the opposite abutment or first pier, and so on, anchoring the shore end during projection by weighting or guying.

I am told that Cottrell convinced a bridge company at St. John, N. B., that he could span the 500-foot gap at the rapids there in that way, and actually projected his latticed trusses into space 100 feet; but, becoming frightened by sure evidences of coming catastrophe, he suddenly left town for other parts. Later he succeeded in erecting a wooden lattice bridge in this way in Maryland, with the help of an engineer, who made provision for increased strength in members where the strains were temporarily reversed during the projection.

Cottrell was clever at figures without a deep knowledge of mathematics, and published a pamphlet containing some of his discoveries, one of which was that Archimedes was wrong in giving the approximate value of π as 3 1-7 times the diameter. The humble author of the pamphlet found it to be $3\frac{1}{8}$ times. One proof adduced was that, with this value, many problems could be solved without fractions, the circles squared, etc. To test his new ratio he had encircled an old millstone with a thin carpenter's shaving, and found the circumference to be exactly $3\frac{1}{8}$ times the diameter.

Later he saw the advantage of projecting a half span from each shore, and conceived and patented the design shown in the photograph.

He came to Boston about 1867 or 1868, and was employed at the Chickering pianoforte factory, where he made the acquaintance of a fellow-workman, Levi Liscom, who had built wooden bridges in New Hampshire and Vermont. He convinced Liscom, and through him several men of financial influence, that his patent solid lever projected without false work from opposite shores was the coming bridge. A company was formed, and the Oliver street gap gave the opportunity for a conspicuous advertisement. The contract price was $1000.

It will be noticed that the arch springs from a point far back from the fulcrum point of the levers. The reason for this was a brilliant discovery of Cottrell's, viz., that the thrust of the arch could be utilized for balance power to help support the levers. The arch was an afterthought, and was added to prevent the sagging of the slim center ends of the levers. The theory advanced later was that the levers sustained the dead load and the arches the live

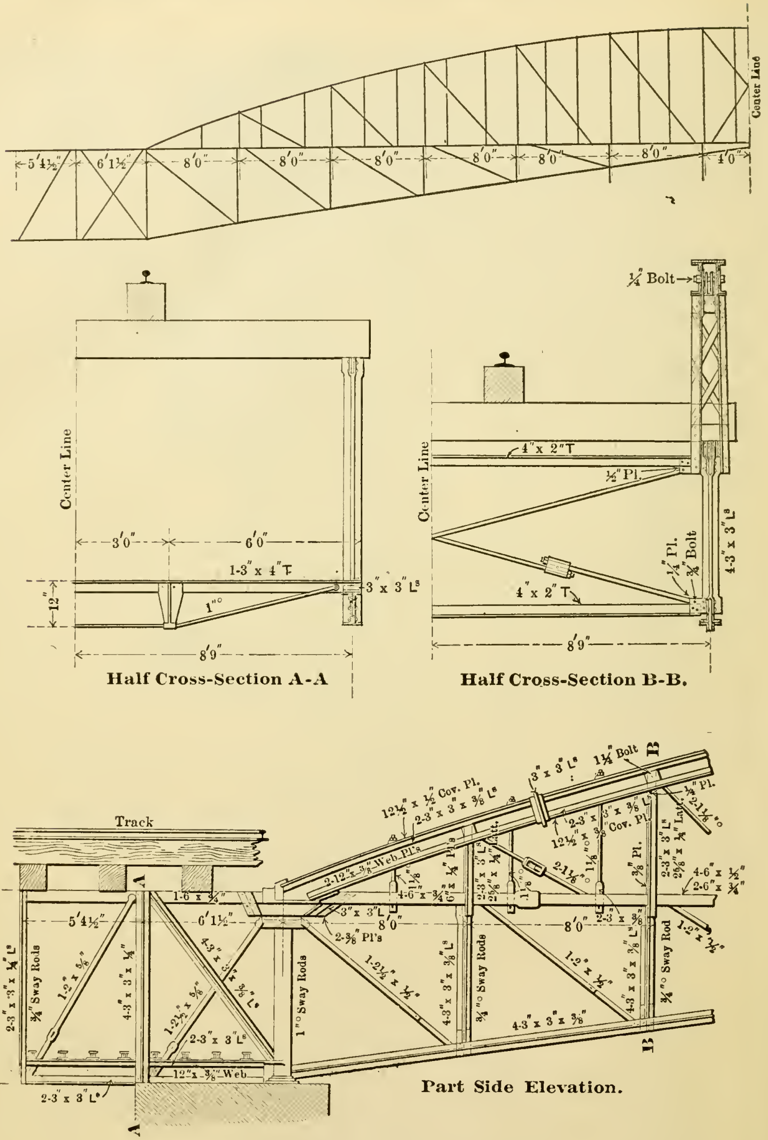


FIG. 3. MAGUAGADAVIC BRIDGE.

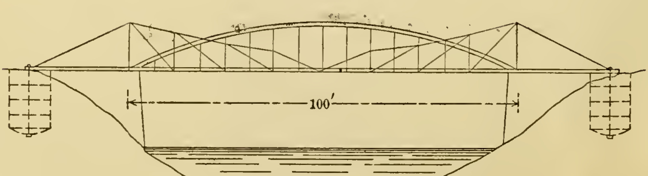


FIG. 4. OROMOCTO, SOUTH BRANCH.

load. In practice, owing to debris working under the shore ends of the levers, they failed to act, and the arches carried both live and dead loads.

This bridge afterwards fell from the crumbling of the clay and gravel banks under the fulcrums.

The one important feature of this bridge worth mentioning and recording is the use of the cantilever principle to erect without false work, the first case of the kind, as far as I can learn, in this country.

Mr. Theodore Cooper, in an article on bridges published in Vol. 21, page 1, of the "Transactions of the American Society of Civil Engineers," says that the first use of cantilevers in bridge erection was by Capt. James B. Eads, in 1874, who used balanced cantilevers 250 feet long in erecting the 500-foot steel arches of the St. Louis Bridge. According to the *Scientific American* this occurred one year earlier, in 1873. Mr. Cooper further says that the first cantilever bridge built in this country was over the Kentucky River, in 1876-77, by C. Shaler Smith; the Niagara cantilever in 1883, the Frazer River cantilever in 1885, both designed by C. C. Schneider, and the St. John, N. B., cantilever in 1885. Later instances are well known.

In a book, published in 1811 by Thomas Pope, entitled "A Treatise on Bridge Architecture," the author describes at length his ideas for a flying pendant lever bridge with diagrams. It does not appear that Mr. Pope's scheme was ever carried out in practice.

The agents of the Solid Lever Bridge Company started out to introduce the new bridge, but were met with the demand from the railroads for iron instead of wood. One wooden highway bridge was built near Worcester. They declared the principle just as well adapted to iron, and made contracts for iron bridges at about the price of wooden ones; among them five bridges on the European and North American Railroad between Bangor, Me., and St. John, N. B., with spans varying from 50 to 154 feet. As a substitute for the laminated deal construction of the levers, it was proposed to use channel iron set on edge, riveting the flanges together, building up the solid lever by projecting the channels successively, as before with the plank. The backs of the channels were to be crossed by vertical tee-bar stiffeners. A tin model of a 25-foot span was made and set up in the corridor of the Merchant's Exchange building, and the heavy men of Boston walked across it and pronounced it remarkably stiff and strong.

Hundreds of tons of beams, channels, angles and tees of various sizes were bought in England and Europe before any working

drawings were made. Crude drawings for a 50-foot span railroad bridge over Costigan Brook, near Bangor, Me., were the first made; and negotiations for the shop-work were under way when it became evident, to the few who had money at stake in the enterprise, that an engineer was necessary; and in 1868 Mr. C. H. Parker (later a member of this Society) was called in. His task was a peculiar and difficult one, viz., to make, largely from the great mass of material already bought, safe bridges for railroad traffic with the strains properly provided for, while limited, of course, to the patented arched cantilever type which the company was formed to build.

Mr. Parker at once condemned the *solid* lever and substituted the skeleton form with members in the line of the strains, placed the end bearings of the arches directly over the fulcrum points of the levers, provided separate chords for lever and arch in the longer spans, with expansion joints in levers at the span center and roller-end bearings for the arch. The channels on hand made lever chords and excellent arches; the I-beams were used for posts and struts, pin-connected flat bars for the chord of the arch in the longer spans and plates and angles for various other members. The designs embraced some very unique details. The results gave strong and safe bridges for the loads then in use, at a cost, however, greatly in excess of the contract price, but fulfilling in honorable fashion a number of very foolish contracts.

These bridges (about eight in number) were all built in 1868 and 1869. They were, where necessary or desirable, erected without false work, and all did good service for many years.

The Costigan Brook bridge, 50-foot span, near Bangor, Me., on the Maine Central Railroad, was in use fifteen years, or until 1883. This was the first one of the lot erected, and the only one of the iron bridges having the solid levers.

The Olamon bridge, in Maine, Fig. 2, on the same railroad line, 75-foot span, was in use eighteen years, or until 1886, at which time Mr. J. P. Snow made a report on it, suggesting changes which might possibly prolong its life, but it was decided to replace it by a new bridge.

The Maguagadavic bridge, Fig. 3, 104-foot span, was on the connecting railroad line in New Brunswick. How long it remained in use I have not learned. Mr. Job Abbott, member of the American Society of Civil Engineers, during a trip in New Brunswick, saw this strange bridge, took measurements and had drawings made, from which an illustrated article was prepared and published in the *Engineering Record* of July 27, 1901. Mr. Abbott supposed

Fig. 5. Bridge over Assabet River, West Concord, Mass.

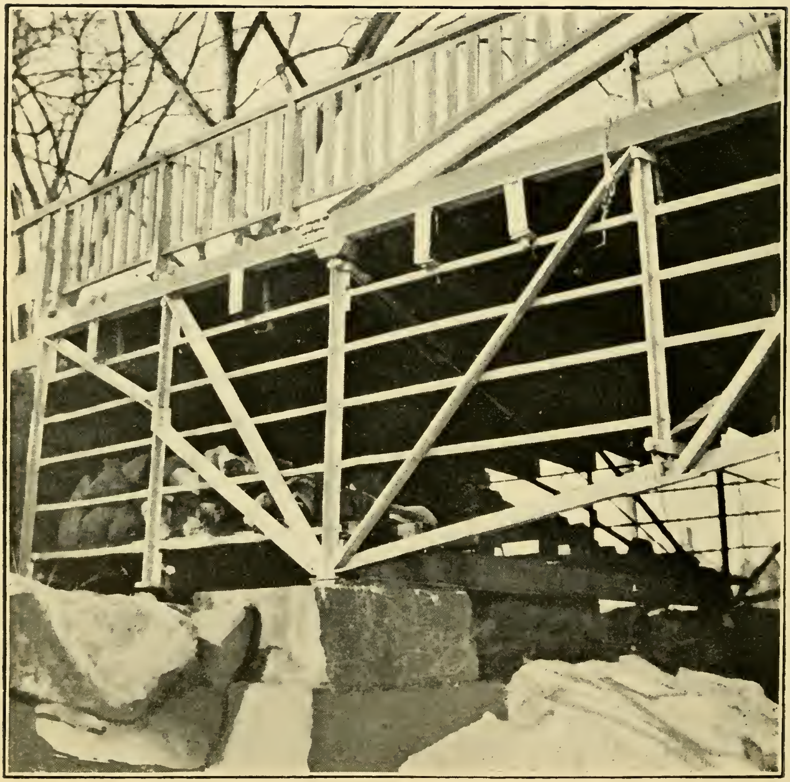


Fig. 6. Shore End. Bridge over Assabet River.

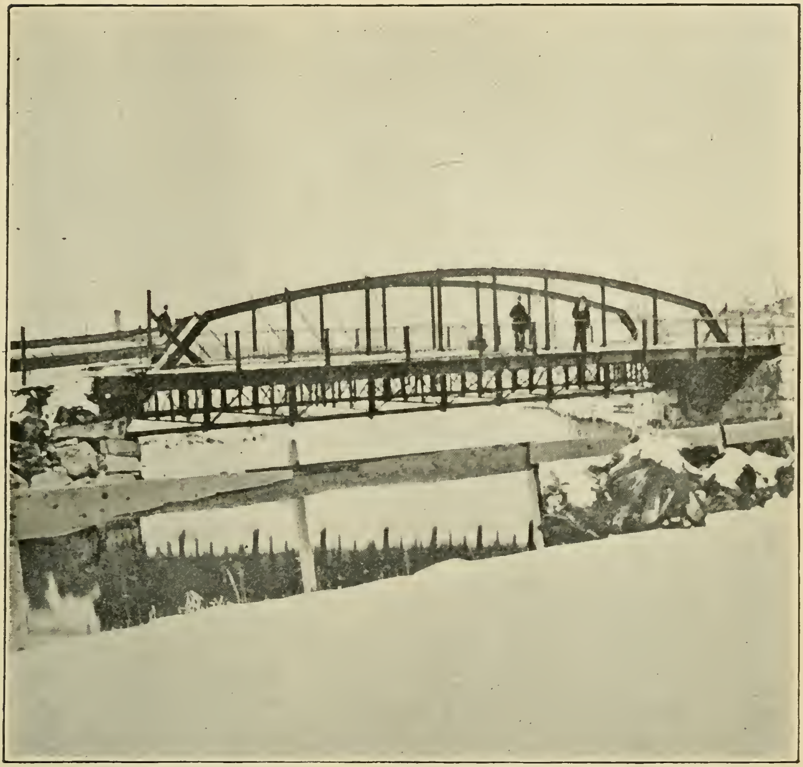


Fig. 7. Bridge at Fitchburg, Mass.

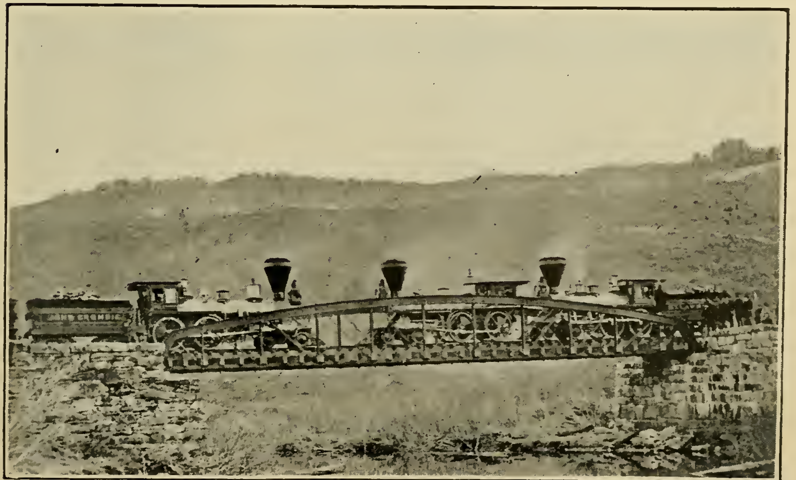


Fig. 8. Bridge at North Woodstock, Vt.

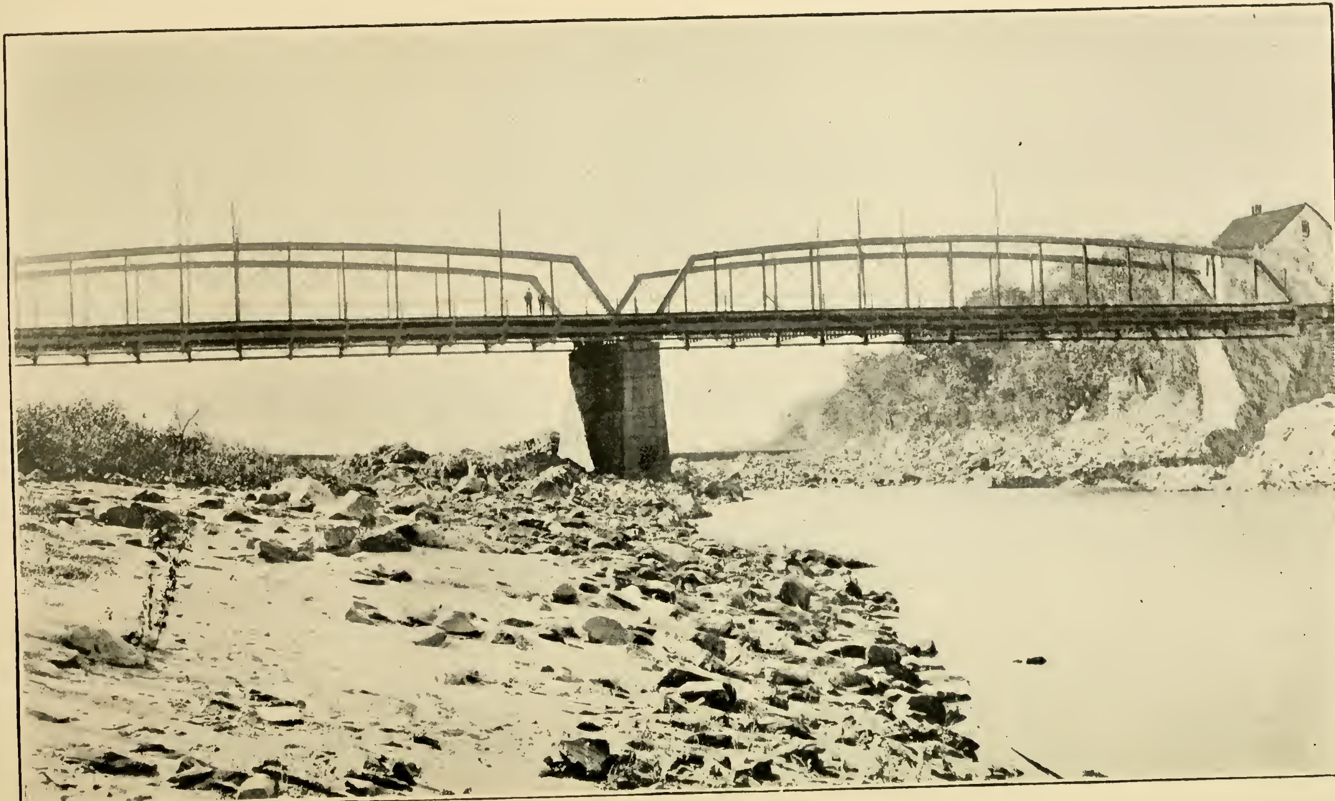


Fig. 9. Bridge over Merrimac River, Lowell, Mass.

that this and the two following bridges, all in New Brunswick, were made in England.

The bridge over the north branch of the Oromocto River, near Frederickton, N. B., 154-foot span, was the best sample of the lot, having separate chords for lever and arch and provision for expansion. It was in use till about 1895; and it is my impression that it was then swept away by a freshet and log jam.

The bridge over the south branch of the same river, Fig. 4, 100-foot span, was unlike all the others in having both levers and arches above the roadway. It had separate chords for arch and lever and provision for expansion. I have no record of the life of this bridge.

A highway bridge, Figs. 5 and 6, was erected at West Concord, Mass., over the Assabet River in 1869, and was in use as late as 1899, when it was replaced by a concrete arch designed by Mr. J. R. Worcester, who can tell the condition of the old bridge after thirty years' service.

Mr. Parker was a firm believer in the cantilever principle; and, at the time when John A. Roebling was urging the suspension bridge for railroads, said that the cantilever bridge would supersede the suspension bridge for railroad traffic, except for the very longest spans. He realized the absurdity of combining the two systems (lever and arch) in one bridge and of using the lever for anything but long spans. He made the arch strong enough to carry all loads, live and dead, and placed little reliance on the lever. He made study plans for a cantilever bridge across the chasm at St. John, N. B., over the rapids, where a similar bridge has since been erected; and, in 1876, when the cantilever type was proposed for a railroad bridge across the East River and lower end of Blackwell's Island, he was pronounced in its favor.

The Solid Lever Bridge Company was succeeded, in 1869-70, by the National Bridge and Iron Works, with Mr. Parker as chief engineer, now free to choose the type of bridge he thought best in each case. Between 1869 and 1876 the new company built many truss bridges and iron buildings, including three bridges across the Merrimac River, the Lowell Railroad and Providence Railroad train sheds, the Boston post-office roof and many highway bridges throughout New England. To one form of truss Mr. Parker felt justified in giving his name and secured a patent, viz., a truss with inclined end posts, curved top chord and vertical interior posts, otherwise a Pratt truss. Examples of this truss are shown in Figs. 7, 8 and 9. The advantages claimed were the shorter posts for the increasing strains toward the ends, more equal strains

throughout the chords, retaining the good points of both the bowstring girder and the rectangular truss.

From 1871 to 1874 Mr. D. H. Andrews was employed as assistant engineer, and gave much thought to the working out of the train sheds for the Lowell and the Providence railroads and of other structures.

In 1876 the company failed, and in the same year the Boston Bridge Works was formed by Mr. Andrews, who purchased a considerable portion of the plant of the old company and retained many of its employes, a number of whom are still with the Boston Bridge Works, occupying responsible positions.

From 1876 to 1884 Mr. Parker was in Pittsburg, Pa., as general manager of the Fort Pitt Bridge and Boiler Works. In 1877 this company built, for Jas. B. Eads, the iron dredge boat *G. W. R. Bailey* for use at the Jetties below New Orleans.

From 1884 to his decease in 1898 Mr. Parker was in Boston, engaged in the manufacture of portable hoisting engines and mining machinery, ten years with Edward Kendall & Sons and four years in business for himself. His record in the bridge line was creditable. His bridges were all made for specified loads, and careful strain sheets were made in each case. Many of his bridges are still in use as originally built; some have been outgrown and replaced, some have been strengthened for heavier loads and are still in use, but none ever failed, and this is more than can be said of a number of bridges built during the same period by others.

DISCUSSION.

Mr. Joseph R. Worcester.—I am very glad of this opportunity to testify to the remarkable work in the bridge line which was done by Mr. Chas. H. Parker, with the assistance of his brother, the speaker of the evening, during the early seventies and even earlier.

Sufficient credit has never been given Mr. Parker for the advance in the science of iron bridge building which was due to his persistent study and the painstaking care with which he worked up his designs.

It has been my fortune to examine a number of bridges built by Mr. Parker, among which are those across the Merrimac at Haverhill and at Lowell, at Taunton, at Pawtucket, R. I., at Northampton, at Lawrence, as well as the cantilever arch at Westvale Village, Concord, Mass., and in each case I have been greatly impressed by the skill and faithfulness with which the work was executed.

A few points of weakness appear in each, according to modern

methods of figuring, but so well was the work done, that the weakness rarely shows itself after many years of use. For instance, we find in many cases floor beams in the form of an open Pratt truss, the posts and chords composed of two angles, and the diagonals of a single flat bar, with the connection at the intersection often made by means of a single $\frac{3}{4}$-inch rivet. This rivet, under the heavy concentrated loads of to-day, will sometimes have a phenomenally high strain per square inch in bearing, but I have never found one seriously weakened and rarely one loose. This is apparently a case where Mr. Parker knew more about what a rivet was good for than we do to-day.

Another point in these bridges which figures high but, so far as I am aware, never gives out, is the bottom chord pin. The joints in the chords are usually outside the panel points, the flat bars meeting end to end and having splice plates on each side of each bar connected by single pins or, rather, bolts, which seem wonderfully small, according to our methods of figuring, but they are all right so far as any evidence of distress is an indication.

The principal trouble with the old bridge at Westvale was that the arches were insufficiently braced transversely. The floor beams in this case were wooden, and, of course, it was impossible to attach the trusses to a wooden floor in a manner wholly permanent and satisfactory. The consequence was that the arches became badly bent laterally. No restriction was ever placed upon travel over the bridge, and nobody ever suspected its weakness, apparently, until it was examined with a view to the possibility of carrying an electric road over it.

In general, it may be said that Mr. Parker's trusses were of ample strength, and in appearance much more artistic and graceful than anything built up to their time and than much which has been built since. The weak spots, if any, can generally be found in his floor systems, which were built for far lighter concentrations than are now used in the streets.

The most remarkable work will be found in the details which, while wholly new and original at the time, have now come into general use in many cases, and where they have been superseded it has often been on account of inventions, such as the manufacture of upset eyebar heads, which allow different types of construction from what was then possible. In this particular part of the work the speaker of the evening found his field, and he is entitled to his full share of the credit.

Mr. J. Parker Snow (by letter).—I wish to indorse and supplement what Mr. Worcester has said as to the credit due to the

author of the paper for his part in the development of iron bridge building in its early stages in New England. His rare grasp of structural detail has, in my opinion, left a mark on our practice of bridge building that will be carried far into the future.

The paper is a valuable bit of history, and an interesting addition to it would be a description of the progress of the author's personal practice in planning the shop-work for building bridges when nothing but the strain sheet was furnished him from which to work. That is, in clothing a skeleton diagram with sufficient metal to carry the prescribed strains and in arranging proper connections to secure the members together. This was the author's peculiar field. It was really engineering, but it went by the name of pattern making. A full history of this "pattern making" would, I feel sure, show the origin of some of our best practice to-day.

The instances of startlingly high strains in rivets and pins mentioned by Mr. Worcester is, as he intimates, rather a reflection on our modern practice than on the old designs. Our experience shows us that some of our theories of modern designing are wrong, but we do not know enough yet to correct our theories, and it will not do now, as it would thirty-five years ago, to design by guess.

The author is in error as to my connection with the Olamon bridge. It was the bridge over the south branch of the Oromocto River in New Brunswick that I investigated. This, as the paper states, had the arch and levers above the floor. Mr. D. H. Andrews, proprietor of the Boston Bridge Works, examined this bridge in the winter of 1882-83, and from drawings which he procured I made calculations from which to investigate its strength. I think the arch and lever were originally so connected that sufficient horizontal play was allowed for expansion, but, as these connections gave trouble, for the reason explained farther on, they were in course of time riveted up solidly, and then the structure was firmly fixed at the ends by the lever counterweights and made continuous at the center by the arch, hence there was no chance for contraction or expansion except by tearing these connections apart.

According to my investigation the inherent defect of the structure was the connection of the two systems at every panel point. The deflection curve of an arch is approximately a parabola, everywhere convex downward. The deflection curve of a pair of levers has a cusp at the center and is everywhere concave downward. If these two systems are constrained to deflect to the same curve by being riveted at each panel point, the connections will be severely tried at certain points.

The arch of the bridge in question was a very much more

rugged member than the levers, and hence the latter suffered. The rupture of members near the extremities of the levers, and the constant tearing apart of the connections between the arch and levers, caused anxiety as to the strength of the bridge, and led to the call for its examination by Mr. Andrews. My computations led me to think that, if the levers were cut free from the arches except at the center, the bridge would be amply sufficient under the loads in use at that time.

Mr. David A. Hartwell.—I am not certain that it is quite the thing for a new member to make remarks, but I have been much interested in Mr. Parker's paper. Being from Fitchburg, I was especially interested in the Parker patent bridge and the historical matter which led up to its inception, as we have three of those bridges in use at the present time. The Rollstone street bridge has a span of 108 feet, and was erected in 1870; the Kimball street bridge has a span of 90 feet, and was erected in 1870; and the Circle street bridge has a span of 73 feet, and was erected in 1871. The Circle street bridge has no sidewalk, but the other two have walks on each side outside the trusses. These bridges are all within the built-up portion of the city, and are subjected to a constant and at times a heavy traffic of the teams from the granite quarries. All three bridges are in good condition, and I see no reason why, after over thirty years of continuous service, they are not good for years to come. We have a 20-ton road roller, but I have never allowed the street department to drive the roller over any of these bridges, as I have doubts as to the ability of the structures to sustain such a concentrated load.

THE BURNING OF PULVERIZED COAL.

By C. O. Bartlett.

[Read before the Civil Engineers' Club of Cleveland, May 12, 1903.*]

To burn coal in a powdered form successfully, three things are necessary, (1) uniformity of moisture, (2) uniformity in size of grain, and (3) the amount of air required for perfect combustion. In my judgment, it is impossible to get perfect combustion by feeding coal in different states of moisture.

First. Coal varies in moisture from 4 per cent. to 15 per cent. During the summer season, especially, ordinary bituminous coal frequently has not more than 4 per cent. moisture, while during the winter and spring or during the rainy season, and especially when the coal is saturated with water and then frozen, the same kind of coal will contain as high as 15 per cent. moisture, and much of this moisture in the form of ice. We cannot expect to get the same results by burning coal with this amount of moisture as can be had by burning the same kind of coal with 4 per cent. moisture. Therefore, it is absolutely necessary to have the coal uniform as to moisture.

Second. It is impossible to get the best results by burning large pieces of coal together with the dust of the coal. The coal must be reduced to grains of equal size. In other words, it must be powdered or pulverized. It should be 80 mesh fine.

Third. The right amount of air or oxygen is necessary for the perfect combustion of any kind of coal. I believe it is generally conceded that about 140 cubic feet of air are required to burn a pound of coal. The admission of air cannot be successfully controlled by natural draught. Forced draught, either of compressed air or by a fan or blower, must be used. The blower is by far the cheaper.

If the three requisites named are secured, perfect combustion can be had, and perfect combustion means:

(a) No black smoke.

(b) No cinders, and very little ashes.

(c) A saving of practically 40 per cent. in the amount of coal used.

A test was made on a 60 x 18-inch horizontal tubular boiler, of about 125 horse power, and the tests were made as follows: First we would run a day on powdered coal, the next day on slack

*Manuscript received May 20, 1903.—Secretary, Ass'n of Eng. Socs.

coal and the next day on run-of-mine. We afterwards made a test of longer duration, running 88 hours on powdered coal and 48 hours on the same kind of coal without drying and pulverizing and by hand firing, and the gross saving was found to be about 40 per cent. in the amount of coal used. Six per cent. of moisture was taken out of the coal. When burning the powdered coal, the amount of ash did not exceed 3 per cent., while in the ordinary way of firing it was a little over 19 per cent.

In making this test there was a slight variation in the power used, but not enough to make any difference in the result. Every pound of coal was carefully weighed, so that no mistake could occur.

It is readily understood that from this 40 per cent. in saving must be taken the cost of crushing (when lump coal is used), drying, pulverizing and feeding; and these different items we will now consider:

I will take it for granted that slack coal is used, that it is just as cheap as run-of-mine coal, if not cheaper, although, if this system should come into general use, there would of course be no difference in the price, for the reason that the coal miners would simply sell their coal in the form of slack; that is, they would crush it at the mines.

The first matter to consider is the cost of drying. Our firm has built dryers for many years, and I am quite familiar with this part of the business. We are always willing to guarantee to evaporate 8 pounds of water or moisture by the use of 1 pound of fuel. For the drying of coal we recommend the use of the rotary cylinder dryer, using direct heat, and the products of combustion passing on the outside of the cylinder only. In some few cases the products of combustion are first allowed to pass on the outside of the dryer, then to pass through the coal, and when this is done it is safe to estimate on a basis of 10 pounds of moisture evaporated by 1 pound of fuel.

But the passing of the products of combustion through the dried coal is, to say the least, a little risky, and no risk under any circumstances should be taken in the handling of coal dust, although we are doing this in some cases. I had the pleasure of talking with Mr. Wilson, of the Schwartskopf Coal Dust Firing Syndicate, of Haydock, England, who was sent here by his company to investigate the merits of our dryer, and he said that in England they would not, under any circumstances, think of passing the products of combustion through the coal while it was being dried. This company has experimented very largely in the burning of pow-

dered coal; in fact, they claim to have spent sixty thousand dollars in experimenting and in putting their system on the market. They are now introducing it in the United States. The Illinois Central Railroad passenger depot, Chicago, has been using one of that company's dryers. Therefore, taking everything into consideration, I think it is safe to estimate the cost of drying the coal on a basis of 8 pounds of evaporation to 1 pound of fuel. Estimating on a basis of $2 per ton for coal and taking the loss in moisture at 5 per cent., the cost of drying and the loss in moisture will be less than 12 cents per ton. This estimate is based on drying not less than 40 tons a day. If the amount to be dried is less, the price will be correspondingly higher, and if the amount be 100 tons a day, the price will be a little, but not very much, lower.

Second. The cost of pulverizing, with one good mill, using 25 horse power, 4 tons of coal can be pulverized in an hour. The cost will be somewhat reduced by improved machines which are fast coming into use. At the present time there are three systems:

The French Buhr or Emery Wheel system.

The Huntington or Centrifugal type.

The ball or tube mill system.

To these I might add the Kent mill, which is now being put on the market, and in which the pressure of the rolls against the casing is obtained by means of screw pressure, which adds to the capacity and at the same time admits of great reduction in speed, adding greatly to the life of the mill. There is also at present on the market a new invention by a Cleveland man, and, I think, a member of this Club, Mr. Fleming, which, in my judgment, will still further reduce the cost of pulverizing the coal. At present it is safe to estimate on a cost of ten cents per ton for pulverizing.

Third. The cost of elevators, conveyors, bins, cost of running blower or feeder, interest on investment and wear and tear should not amount to more than 10 cents per ton, and probably not more than 5 cents per ton, making the total cost of drying, shrinkage, pulverizing, feeding and cost of driving the machinery, interest on investment, etc., in quantities of 40 tons a day, about 32 cents per ton.

This shows, on 40 tons of coal a day, coal costing $2 a ton, a net saving of a little less than $20 a day, or 50 cents per ton.

Another important factor, which I have not considered, is the doing away with the fireman, as in the use of this system no fireman is required. The fireman's wages are therefore saved. Also, there is not more than one-third as many ashes, and there are no cinders at all.

I have shown the credit side of this matter, and I will now consider the other side, or the obstacles to be overcome in successfully burning pulverized coal.

To burn pulverized coal economically it must be burned in fairly large quantities; in other words, I do not think it would pay to put in a drying and pulverizing outfit unless the amount of coal used is at least 10 tons per day. In large cities this difficulty can be obviated by having a central drying and grinding plant and selling the pulverized coal to small consumers. In this case it would be necessary simply to put in a feeder, for feeding the coal in a powdered form, and a tank for holding it.

The next obstacle, and one which I consider of very great importance, is the danger arising from storing large quantities of powdered coal. That there is danger in doing this I have no doubt.

From the best information that I have been able to obtain I do not think it is practical to store large quantities of pulverized coal for any length of time, and this means that it would not be practical to dry and pulverize the coal at the mines and ship it in this form. Neither would it be practical, in my judgment, for a boat, say the *Northland* or the *Northwest,* which now use about 500 tons at one trip, to put in that amount of powdered coal at Buffalo or Cleveland, with the intention of storing it for the round trip. The only way would be to store the dried coal and to pulverize and feed it on board the boat as they need it. In any case, the dust should be stored in iron receptacles.

The next question, and quite a serious one, is the construction of the arch. In our experiment we used the Rowe system, which consists in blowing the pulverized coal, by means of an ordinary fan or blower, up against an arch over the fire. In other words, burning it in suspension. The arch wall becomes very hot and immediately ignites the coal, and when the proper amount of air is used the combustion is perfect. We find that a 2-ounce pressure is best for this purpose. It will be readily understood that, in order to withstand this excessive heat, the best kind of arch wall is necessary, and that specially constructed brick should be used. While this is really quite a serious question, I do not doubt that it will be satisfactorily answered. Mr. Fred. Siegheim, of Germany, has an invention for covering the arch wall, by which it can be made to withstand a tremendous heat, up to 3000 degrees or more, without injury, and to last for a long time; in fact, until the draught of air has worn away this material. As near as I can ascertain, this mixture is composed largely of the dust of carborundum, which is now being manufactured in large quantities

at Niagara Falls. In taking the matter up with this company, I find that Mr. Siegheim has contracted for the exclusive output of this dust for five years. I consider this a very important invention and well worthy the most careful consideration of the engineers of the United States. It seems a little humiliating that the Germans should get ahead of us, but such seems to be the case.

As near as can be estimated, the cost of an outfit for, say, 40 tons per day of 10 hours, will be as follows, using slack coal:

Dryer, estimated cost	$1,500.00
Pulverizer, estimated cost	2,500.00
Feeders, estimated cost	1,000.00
Conveyors, elevators, bins, etc., necessary handling of machinery...	2,000.00
Total	$7,000.00

Of course, this cost will vary considerably according to circumstances.

Among other important advantages of the use of pulverized fuel is the absolute elimination of smoke, and this is one that ought to be considered by every manufacturer, especially in the cities. When our health officer says, as he has said on several occasions, that the death rate is considerably higher in the smoky sections of the city than elsewhere, and especially in pulmonary troubles, it ought to be sufficient to induce us all to do our best to do away with the smoke nuisance. Most of us have to get our bread and butter in the central part of this city. To live in a cloud of smoke must necessarily weaken us physically and shorten our lives. Therefore, every manufacturer should do his utmost in every way to eliminate this smoke nuisance.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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ACTION OF SEA WORMS ON FOUNDATIONS IN BOSTON HARBOR.

BY F. W. HODGDON, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Remarks at meeting of that Society, February 18, 1903.*]

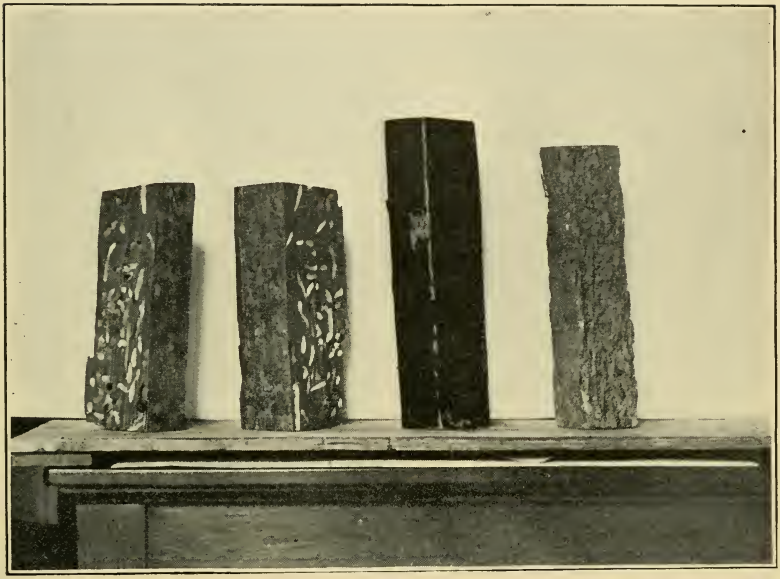
THE trouble from worms in Boston harbor is due principally to the *limnoria terebrans,* a small worm which eats timber from the outside. In attacking piles it eats on all sides of it, the principal activity being a foot or two below low water mark, and it eats in very much as a beaver cuts off a tree, eating away the wood until only a small section not much larger than a pencil remains at the center, which is generally broken off by the waves or other forces. The way in which it eats into plank is shown by the sample marked "a" (Fig. 1) which I have here. This was taken from a bulkhead built through the center of a wharf on the Commonwealth Flats at South Boston, built for the Metropolitan Coal Company, and shows the results of the work of the worms for two seasons. This other sample marked "b" is from a plank taken from the same bulkhead at about the same elevation, but this second one was treated by painting it over with carbolineum avenarius, a patented wood-preserving preparation. At the time the bulkhead was built it was desired to get some information as to the value of the preservative, and a portion of the spruce planking and timbering was coated with it, being applied hot with a brush after the planks had been dried to a certain extent. As you can see, the coating has practically preserved the plank from the attack of the worms, only a few holes having been bored into it, and these in spots evidently where the coating had been worn off in the handling of the timber.

*Manuscript received August 13, 1903.—Secretary, Ass'n of Eng. Socs.

These worms are very active in the clear salt water in the outer harbor, and I am told that where the water is clear, as it is in the outer harbor, they will eat off a spruce pile in about five years. Around the city wharves, where the water gets foul from sewage and other refuse thrown into it, the worm cannot live, and further up in the rivers, where the inflow of fresh water is so great as to materially reduce the proportion of salt in the water, the worm is not found.

Another worm, known as the *teredo navalis,* or ship worm, has given us very little trouble in Boston, although it is found all along the Atlantic coast. South of Cape Cod it is very active, and at Norfolk I am told that it will eat off an oak pile in one year. This worm acts in an entirely different manner from the *limnoria,* as is shown by samples "c" and "d" (Fig. 1). It enters the timber through a very small hole, and after it is inside, grows and bores out a chamber about one-quarter of an inch in diameter, winding through the timber in an irregular manner, but never boring out through the face, but coming so close to the face of the timber that holes are very easily forced through it.

The only real case of this worm in Boston harbor that I know of occurred a few years ago in some new scows owned by one of the dredging companies. These scows were built during the winter at Bath, Me., of timber brought from Georgia. In the spring they were put in service first in the upper harbor of Boston, and after being in use a short time there were sent down to the mouth of the harbor where the main channel was being dredged. After being in use for a few months they began to leak very badly, and upon examination it was found that their bottoms were honeycombed by the *teredo.* Upon an examination of some old scows built of spruce timber, which had been lying alongside of the new ones, it was found that they were also eaten to a considerable extent. The scows were withdrawn from service and replanked, and after being caulked, sheathing paper was placed over the bottom, and outside of this 1-inch boards were spiked to the sides and bottom of the scows up to the light water mark. After this no further trouble was had with them and no other scows appear to have been affected. One peculiarity of this worm is that it will not bore from one plank into another, no matter how tight the joint may be, but will always stay in the timber which it has first entered. Relying on this fact, timber has often been protected by nailing inch boards on the outside of it, the worms entering the inch boards, but not crossing the joint into the main timber.



d c b a

FIG. I.

I have heard some statements that the worms had been found in and around Boston at other points, but it has always been reported that they were dead. The *teredo* attacks hard woods, such as oak and the like, often more readily than the soft woods. Very soft wood like the palmetto it will not attack at all, while the *limnoria* is much more destructive to the soft woods than to the hard. While it will readily eat the spruce piles, I have never seen an oak pile which was eaten sufficiently to injure the pile, and I have examined some piles which have been in place over fifty years.

To protect our sea-wall foundations from these worms we have to be very sure that the piles are completely covered by the riprap or filling around them so that the worms cannot get at them. At the pier built by the New England Railroad Company at South Boston, the material surrounding the heads of the foundation piles at about low water mark was washed away at a few places and I had the heads of the piles examined and found that the worms had got in and eaten the heads of the piles to a considerable extent. The railroad company had the filling replaced, and that undoubtedly stopped the further action of the worms.

In a wall which I designed and built about two years ago, in order to be sure that the heads of the piles were fully protected, the piles, for a distance of about 3 feet below low water mark, were surrounded by concrete, which came up over the heads of the piles and was leveled off to receive the stone sea-wall. In front of this the riprap was placed. The ordinary method of capping the piles in these sea-wall foundations is to cover them with a grillage of timber or plank on which to start the stone masonry. In order to get the foundations as low as possible the work has to be done at times of extreme low water, and as these occur only for a short time each month, the work is often very much delayed. By using concrete it can be placed when the tide is not so low and the work is facilitated very much, and also it protects the heads of the piles much more thoroughly. Another advantage is that it is very difficult to be sure that the riprap around the piles is filled in solid under the timber grillage. In the case of the concrete it has to be supported on this riprap until it sets, and therefore it makes a solid connection with the riprap.

DISCUSSION.

Q. Do these worms work in summer or in winter?

Mr. Hodgdon.—Practically only in summer and in warm weather. The *teredo* is very active on the south shore of Massachusetts; it acts only in the summer months. The work of the

teredo is all done below the level of low tides. At about 1 foot below low water you begin to find them.

Mr. Fernald.—How far North, Mr. Hodgdon, does the *teredo* work?

Mr. Hodgdon.—It apparently does not come into Massachusetts Bay. They have them at Halifax and Nova Scotia. It is a smaller worm than in the South; it may be that cold weather keeps them from growing as large here as in the South.

Those in the dredging scows were quite large. I have seen some about the same size that came from Southern ports.

Q. Will the *teredo* attack lumber that has been treated by kyanizing or other process?

Mr. Hodgdon.—I don't know about the kyanizing, but at the Norfolk navy yard they have a timber dry dock and the outer platform and gate was built of creosoted timber and held the worms off for a long time. The worm in that vicinity will destroy an oak pile in one season, but this creosoted work held, I think, ten or twelve years, then they found the worms had got into it and they had to renew it. Creosote cannot be forced into long-leaf pine, as it is too solid. They have to use the softer, spongy short-leaf pine, in order to get sufficient oil into it to preserve it.

Q. I would like to ask Mr. Hodgdon in that case of the old Boston Electric Light Company's station on Summer street, if the appearance of the pile heads was exactly identical with that sample of the worm of the *limnoria?* I think that was at grade 7½.

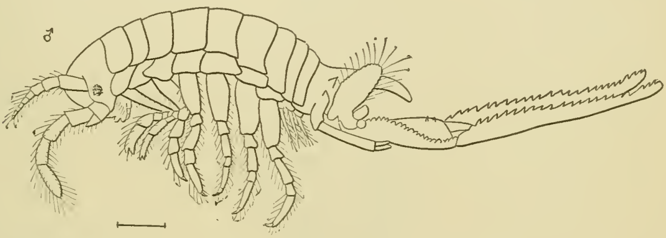
Mr. Hodgdon.—The planks that are in the wharf that this sample was taken from were in a spruce bulkhead that was built through the middle of the wharf to prevent the waves from driving through. The upper portion of the plank was not attacked at all, and almost invariably I found the worms eating just above the mud and up to just below low water. That is where they get in their work; it is where they are covered up by the water all the time.

Mr. Henry Manley.—In the year 1888 a careful examination of the pile bridges in the city of Boston was made with special reference to the danger from marine worms or timber destroyers. It came about through an accident on the bridge of the Fitchburg Railroad over the Charles River, caused by the giving way of overloaded oak piles. One of the broken piles showed a single hole about as large as a pipestem, which may or may not have been bored by the *teredo*. The fact that this hole was found was exploited in the papers, and an examination of the bridges belonging to the city was ordered by the city government. A special report was made in October, 1888, and in the regular annual report of the

city engineer for the same year some of the results of the examination were given in more detail. The report quotes from "The Fisheries and Fishery Industries of the United States," by George Brown Goode, 1884, a publication of the United States Fish Commission, and as it is the best concise description of the *limnoria* with which I am acquainted, it is here reproduced.

THE GRIBBLE OR BORING LIMNORIA—*Limnoria Lignorum, White.*

"The little crustacean pest, which measures less than one-fifth of an inch in length, is a very common inhabitant of our Atlantic coast from the Gulf of St. Lawrence to Florida, and also occurs abundantly on the coast of Great Britain and of other parts of Europe. In spite of its small size, it is very destructive to all kinds of submarine woodwork, which it rapidly eats away. Its body,

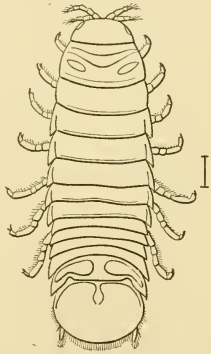


Chelura Terebrans; Male; Lateral View. Enlarged about Twelve Diameters.

which is subcylindrical in shape, consists of fourteen segments, the anterior one being the head; the two ends are rounded and the sides are nearly straight and parallel to one another. The first seven segments, not including the head, bear each a pair of short legs. It makes its burrow by means of stout mandibles or jaws. In color it is grayish, the upper surface of the body being covered with minute hairs, to which more or less dirt usually adheres.

"The gribble generally lives above and just below low water mark, but has been found at times, though very rarely, as low down as 7 to 10 fathoms. It gnaws burrows into all sorts of sunken or floating wood near the shore, and lumber or driftwood left for some time on muddy shores is pretty certain to be attacked by it. The burrows are made to the depth of about half an inch, and when they become numerous enough to reduce the superficial layer of wood to a mere honeycomb, it scales off, leaving a fresh surface, which is at once attacked. Much damage is done by this little creature to the piles of wharves and other submarine woodwork all along our Atlantic coast, and numerous methods of stopping its ravages have been devised. It has been observed attacking the

gutta-percha of submarine telegraph cables. Professor Verrill describes its habits and the damage done on the American coast as follows: 'It has the habit of eating burrows for itself into solid wood to the depth of about half an inch. These burrows are nearly round, and of all sizes up to about a sixteenth of an inch in diameter, and they go into the wood at all angles, and are usually more or less crooked. They are often so numerous as to reduce the wood to mere series of thin partitions between the holes. In this state the wood rapidly decays, or is washed away by the waves, and every new surface exposed is immediately attacked, so that layer after layer is rapidly removed, and the timber thus wastes away and is entirely destroyed in a few years. It destroys soft woods faster than hard ones, but all kinds are attacked except teak.



Limnoria Lignorum; Dorsal View. Enlarged Ten Diameters.

It works chiefly in the softer parts of the wood, between the hard annual layers, and avoids the knots and lines of hard fiber connected with them, as well as rusted portions around nails that have been driven in, and consequently, as the timber wastes away under its attacks, these harder portions stand out in bold relief.

"'Where abundant, it will destroy soft timber at the rate of half an inch or more every year, thus diminishing the effective diameter of piles about an inch annually. Generally, however, the amount is probably not more than half this; but even at that rate the largest timbers will soon be destroyed especially when, as often happens, the *teredos* are aiding in this work of destruction. It lives in a pretty narrow zone, extending a short distance above and below low water mark. It occurs all along our coasts, from Long Island Sound to Nova Scotia. In the Bay of Fundy it often does great damage to the timbers and other woodwork used in constructing the brush fish weirs, as well as to the wharves, etc. At Wood's Holl it was found to be very destructive to the piles of the wharves.

The piles of the new government wharves have been protected by broad bands of tin plate covering the zone which it chiefly affects. North of Cape Cod, where the tides are much greater, this zone is broader and this remedy is not so easily applied. It does great damage also to ship timber floating in the docks, and greater losses are sometimes caused in this way. Complaints of such ravages in the navy yard at Portsmouth, N. H., have been made, and they also occur at the Charlestown navy yard and in the piles of the wharves at Boston. Probably the wharves and other submerged woodwork in all our seaports, from New York northward, are more or less injured by this creature, and, if it could be accurately estimated, the damage would be found surprisingly great.

" 'Unlike the *teredo,* this creature is a vegetarian, and eats the wood which it excavates, so that its boring operations provide it with both food and shelter. The burrows are made by means of its stout mandibles or jaws. It is capable of swimming quite rapidly, and can leap backward suddenly by means of its tail. It can creep both forward and backward. Its legs are short and better adapted for moving up and down in its burrow than elsewhere, and its body is rounded, with parallel sides, and well adapted to its mode of life. When disturbed it will roll itself into a ball. The female carries seven to nine eggs or young in the incubatory pouch at one time.

" 'The destructive habits of this species were first brought prominently into notice in 1811, by the celebrated Robert Stephenson, who found it rapidly destroying the woodwork at the Bell Rock Lighthouse, erected by him on the coast of Scotland. Since that time it has been investigated, and its ravages have been described by numerous European writers. It is very destructive on the coast of Great Britain, where it is known as the "gribble." The remedies used to check its ravages are chiefly copper or other metallic sheathing; driving broad-headed iron nails, close together, into the part of the piles subject to their attacks, and applying coal-tar, creosote or verdigris paint once a year or oftener.' "

The city engineer's report further says: "The two remaining animals referred to are the *teredo navalis,* or ship worm, and the *chelura terebrans.* The *teredo* is found in warm climates in nearly all parts of the world. In appearance it is a large soft worm, and may grow to the length of 18 inches and to a diameter of $\frac{3}{8}$ inch; it burrows in the interior of the timber, and when it is numerous the timber is soon reduced to a mere shell. It is abundant on the southern coast of Massachusetts, but is not found north of Cape Cod."

Of the *chelura,* the authority already quoted says:

"This very destructive little crustacean, which is of common occurrence on the European coast, from Southern Norway to the Adriatic Sea, has so far been noticed on the Atlantic coast of the United States at only two places, Wood's Holl and Provincetown, Mass.

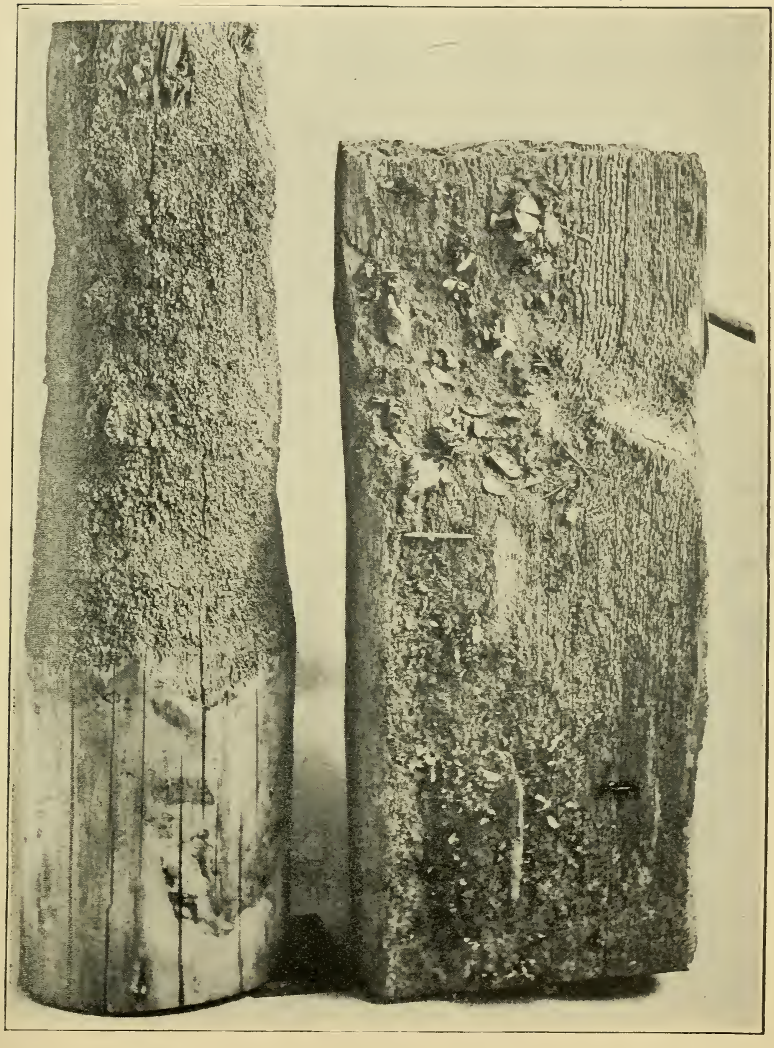
"At both of these localities it was found associated with the 'gribble' (*limnoria lignorum*), in the submerged piles of old wharves. It is more than possible, however, that it is a common inhabitant of our coast, doing a certain amount of the damage hitherto ascribed to other boring animals. Without a careful examination, it is quite easy for an unskilled eye to confound *chelura* with *limnoria,* although they belong to very distinct divisions of the *crustacea.*"

"Specimens of the timber secured by the diver from two localities infested by the *limnoria* were submitted to Prof. S. I. Smith, of New Haven (who first identified the *chelura* in this country), and to Professor Hyatt, of the Boston Society of Natural History, and were carefully examined by them, but no specimens of the *chelura* were found. The sample of spruce timber examined was taken from Broadway Bridge, Boston, at a depth of about 14 feet below low water, and the oak timber came from Chelsea Street Bridge in East Boston, at a depth of about 20 feet at low water. The *limnoria* was abundant in each case."

The steamboat wharf at Deer Island, which was rebuilt in 1879 because of the ravages of the *limnoria,* had been built for twenty-four years. In rebuilding in 1879 larger oak piles were used, but a recent examination has shown that many of the piles have been practically destroyed. The wharf at Gallops Island, built in 1872, is also badly damaged, and many piles will be replaced this season. Wharves at Rainsfords and Long Islands also show serious injuries from the *limnoria.* On the other hand, oak piles in the upper harbor, where the water is more foul, resist much longer, and there are probably many piles in Cragie's Bridge which have been in service for more than a hundred years.

A reference to the inroad of the *teredo* in Boston harbor, alluded to by Mr. Hodgdon, was made in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, in the May number of the year 1894.

A paper by Charles H. Snow (*Transactions Am. Soc. C. E.,* vol. xl, 1898), on "Marine Wood Borers," gives a very complete account of the *teredo* and a less full account of the *limnoria* and other borers.



No. 1. No. 2.

No. 1. Spruce Pile Attacked by the Limnoria Terebrans. The Lower Part Shows the Pile Uninjured, where It was under the Mud.

No. 2. Hard Pine Timber Attacked by the Limnoria.

Oak Pile 23 Feet Long, 16 Inches Diameter. Reduced in Size by the Limnoria Terebrans.

Spruce Piles Destroyed by the Limnoria Terebrans.

Surface of Spruce Pile Attacked by the Limnoria Terebrans. Full Size.

GOLDSCHMIDT METHOD OF METALLURGY AND HIGH TEMPERATURE PRODUCTION BY MEANS OF THERMITE.

By B. Palmer Caldwell, Assistant Professor of Chemistry, Tulane University.

[Read before the Louisiana Engineering Society, May 11, 1903.*]

The notice which has been sent you of this meeting of the Louisiana Engineering Society has stated that I would talk to you about the Goldschmidt method of metallurgy and high temperature production by means of thermite. I am afraid that I may be opening up a subject that is more or less old to some of you, as the daily papers have, within the last year, contained more than one account of the glowing possibilities awaiting the employment of this wonderful substance, thermite.

No sooner are discoveries made in any branch of science than the semi-scientific, semi-popular papers and, in a remarkably short time, the daily journals also light upon them and they form the subject of articles in which properties are ascribed to them far more wonderful than their discoverers had known, and brilliant futures predicted for them far rosier than their nearest friend had ever dared to dream. In proof of this, recall the reception given to Koch's lymph, to the Roentgen rays and very recently to radium and the whole family of radiferous substances.

Do not understand that I altogether condemn these journalistic efforts, for I do not. They are generally founded on a germ of truth, even though they appear to be wholly the product of a fertile imagination. Now, imagination is a good attribute for a scientist to cultivate; one thing is necessary, however, that the scientist draw a sharp line of separation between his facts and his fantasies.

And so thermite has recently had its turn.

The subject, as given, would naturally divide my talk into two parts; the first dealing with metallurgy, or the gaining of metals, by means of thermite; the second, the production of high temperatures by means of thermite. But, as the latter is merely the result of the heat liberated in the chemical reaction that causes the former, both parts must necessarily be considered together.

Now, what is thermite, and what is the nature of the chemical reaction which causes so much heat? Thermite is the name given to a mixture of iron oxide and the metal aluminium in a finely

*Manuscript received August 12, 1903.—Secretary, Ass'n of Eng. Socs.

divided condition. The reaction is the reduction of the oxide of iron to metallic iron by the aluminium which is oxidized to aluminium oxide. As represented by a chemical equation the reaction is:

$$2Al + Fe_2O_3 = Al_2O_3 + 2Fe,$$

or if the ferroso-ferric oxide is taken:

$$8Al + 4Fe_2O_3 = 4Al_2O_3 + 8Fe.$$

We have, then, the formation of metallic iron which is in the molten state beneath a layer of molten slag—the aluminium oxide or corundum.

Why does this reaction take place? Berthelot, whose work in the subject of thermo-chemistry is classical, expressed in his "*Essai de Mechanique Chimique*" (l. xxix) what he called the law of "maximum work": "Every chemical change accomplished without the addition of energy from without tends to the formation of that body, or system of bodies, the production of which is accompanied by the evolution of the maximum quantity of heat." This law he elsewhere states in other words as the "theorem of the necessity of reactions" thus: "Every chemical change, which can be accomplished without the aid of a preliminary action, or the addition of energy from without the system, necessarily occurs if it be accompanied by disengagement of heat." Thomsen, also, more than forty years ago, stated the law of "maximum work."

When viewed rigidly the law of maximum work is found wanting in some respects; nevertheless, the fact remains that when the physical conditions of comparable chemical processes are kept as nearly as possible constant, the process which involves the maximum production of heat very frequently occurs in preference to other processes, or occurs to a considerably greater extent than any of these other processes.

In the reaction before us, then, we may compare the heats of formation of, say, aluminium oxide and iron oxide from their respective elements. If the former is greater we may expect the decomposition of iron oxide by aluminium; if the latter is greater, the reverse reaction will take place. But first let me explain a term which is perhaps a technical one. What is meant by the heat of oxidation? The heat of oxidation of a substance is the quantity of heat produced by the complete oxidation of that substance to form those masses of the products of oxidation which are represented by the chemical formulæ of these products—in other words, the quantity of heat liberated in the combustion of chemically comparable quantities of combustible substances to the formation of chemically comparable quantities of the products of oxidation.

Let us therefore compare the heats of formation of iron oxide (Fe_2O_3) and aluminium oxide (Al_2O_3).

Oxide.	Heat in Calories.
$Al_2O_33H_2O$	594.0
$Fe_2O_33H_2O$	396.4

The difference is nearly 200 calories. By the law of maximum work we should expect the reaction to go as has been indicated. Experiment shows that it does, and that iron oxide is reduced by metallic aluminium to metallic iron; and a large quantity of heat is evolved in the reaction.

So much then for the reaction between iron oxide and metallic aluminium.

If this reaction takes place between these two substances (metal and oxide), does it also take place between others? One answer to this question is the trial of the experiment. But a study of the heats of formation of other oxides and the comparison of them with that of aluminium oxide will also serve the same purpose.

I will give the heats of formation of some oxides of metals and of a few oxides of non-metals. A comparison shows that the heat liberated in the formation of aluminium oxide (Al_2O_3) is far greater than in these cases, and hence, according to the law of maximum work, the tendency for that compound to be formed is very great. And experiment shows that the reaction does take place.

TABLE OF HEATS OF FORMATION OF CERTAIN OXIDES OF METALS AND NON-METALS.

Oxide.	Heat in Calories.
$Al_2O_33H_2O$	594.0
H_2O (solid)	69.8
N_2O_5 (solid)	13.1
SO_2 (gaseous)	71.0
CO_2 (gaseous)	94.3
$Fe_2O_33H_2O$	396.4
$MnOH_2O$	94.8
CaO	131.0
$CaOH_2O$	214.9
SrO	128.0
$SrOH_2O$	214.5
ZnO	85.3
$ZnOH_2O$	82.7
$NiOH_2O$	60.8
$CoOH_2O$	63.4
CuO	37.2

This then covers the metallurgical side of my subject. Of course, you engineers will immediately ask about the costs, and no

thought is necessary to make you see that this method of production of, *e.g.*, iron would so far exceed in cost the ordinary method of reduction of the ore with coke, that its employment for the commercial production of iron is an impossibility, and doubtless always will be. But there is one point to be considered; iron made by the ordinary smelting process is never pure, but contains varying quantities of carbon, some combined in the shape of carbides, the rest graphitic. This iron is pure enough for all the ordinary purposes for which it is intended, but often pure iron is desired, and this thermite method gives it. In the obtaining of other metals like chromium, manganese, cobalt, nickel, which command higher prices, especially those which are used to impart certain properties to iron, this method may be of some commercial value.

It is the other side of the subject that promises more to the engineer, viz., the production of high temperatures, and to that I now turn.

We have seen that in the reaction between metallic aluminium and iron oxide a large *quantity of heat* is liberated. Now, if this heat can be confined within a small space, and is liberated all in a short time, then the *intensity* increases and we have *high temperature*. These two points: (1) The production of the heat through a confined space, and (2) the instantaneous production of it are fully met, so that we have in thermite a notable producer of high temperatures.

Goldschmidt claims that in a suitably constructed and yet simple apparatus a temperature of 3000° Centigrade or 7200° Fahrenheit can be obtained. The temperature of the electric arc has been variously estimated; it is probably between 3000° and 3500° C. The temperature reached in an electric furnace probably does not exceed 1500°-2000° C. But the most important point is that this temperature of 3000° can be obtained by means of thermite in an instant of time, and can be applied conveniently over as small space as desired.

It is to this feature that I would especially call your attention. I am aware that most of you are not mechanical but civil engineers. But you may at any time be called upon to exercise the function of a mechanical, electrical, chemical, architectural or any other kind of an engineer; and I believe it can be truly said of the civil engineer that, chameleon-like, he changes his color quickly and naturally, and appears to advantage in all.

The application of thermite as a heat producer has so far been made to problems of iron welding, especially the welding of street car rails *in situ*, bridge beams and structural iron of all sorts, pipes,

etc. The temperature of fusion of iron is around 1600° C., which is far below the 3000° claimed for this reaction. Other processes which require heat will readily suggest themselves to you, in which the application of thermite may prove advantageous.

A word should be said about the manipulation of the substances. In the production of metals the ore [oxide] is mixed with finely divided metallic aluminium and the mixture placed in some receptacle as a Hessian crucible. On the surface of the mixture is placed a little "kindling mixture," which is itself a mixture of barium peroxide and aluminium. On this is placed a "cartridge," which is a little pellet of the "kindling mixture" with an inch strip of magnesium ribbon sticking out from its center. The magnesium ribbon is lighted with a match, and burns with the evolution of some heat. This heat serves to start the reaction between the barium peroxide and the metallic aluminium which evolves a larger quantity of heat. This heat suffices to start the main reaction—between the metallic aluminium and the oxide—which proceeds throughout the whole mass of the mixture with the evolution of a large quantity of heat. The crucible may now be turned upside down, and the molten metal will pour out together with the molten slag—aluminium oxide or corundum. Or the crucible may be allowed to cool when it may be broken off with the solidified slag, leaving an ingot or button of the metal. In the use of thermite as a heat producer the manipulation is practically the same, varying with the nature and size of the pieces welded. Usually the parts are surrounded at the point of junction with sand, fire-bricks, etc., to confine the heat and the thermite is placed within this improvised furnace.

The production of thermite is controlled by patents in all civilized countries; the substances can be obtained from the Chemische Thermo-Industrie G. m. b. H., Essen-Ruhr, Germany. In Germany the prices are: Thermite, 3.75 mk. per kilo.: kindling mixture, 6 mk. per kilo.; cartridges, 5.50 mk. per hundred.

The following demonstrations were made before the society:

1. The making of carbon-free iron.
2. The making of carbon-free manganese.
3. The making of carbon-free cobalt.
4. The making of carbon-free nickel.
5. The making of carbon-free chromium.
6. The heating of an iron plate.

An iron plate $\frac{3}{8}$ inch thick was placed upon supports so that its underside could be seen. The thermite mixture was placed upon it in the space between three bricks and fired in the usual

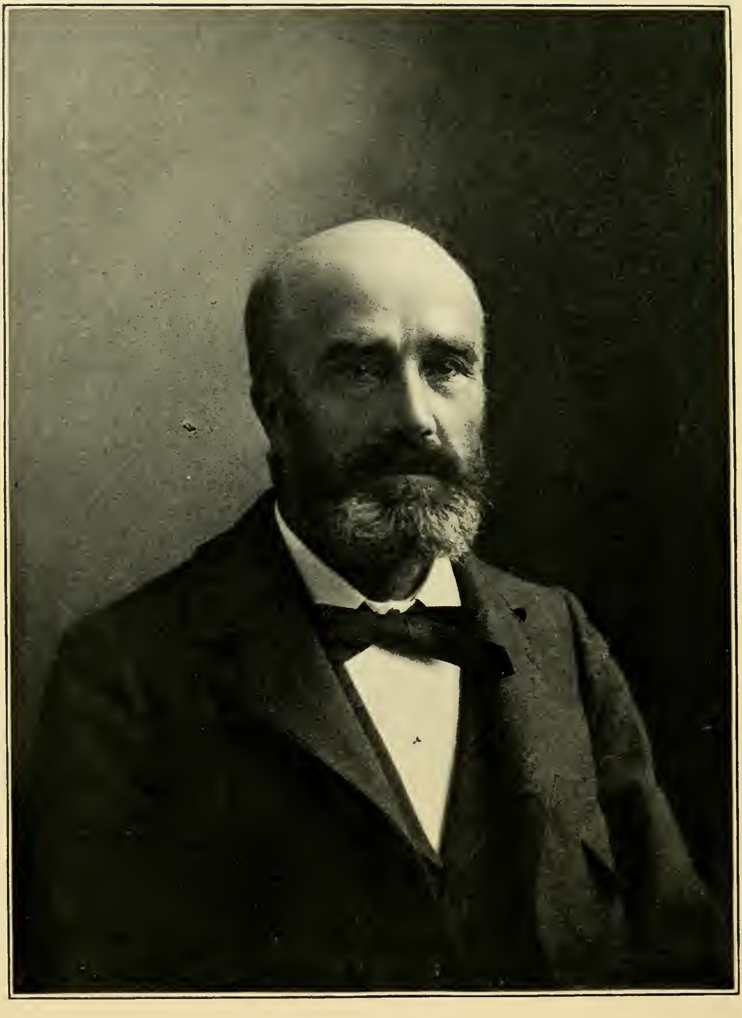
way. Immediately the underside of the plate became red, then white hot below where the reaction was taking place, while 2 inches away or less the plate was perfectly cold.

7. The melting of iron.

Some of the thermite mixture was placed in the bottom of a small Hessian crucible, and into this was pressed a rod of iron $\frac{1}{4}$ inch in diameter. The mixture was then fired. The rod melted down like wax.

See *Marine Engineering*, June, 1903, p. 329, for accounts of application of thermite to ship repair.

The American agent of the Thermite Company is Mr. C. B. Schultz, 149 Broadway, New York.



AUGUST H. SCHIERHOLZ.

Mechanical Engineer. Late Member Technical Society of the Pacific Coast.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXI. SEPTEMBER, 1903. NO. 3.

THE HEYLAND INDUCTION MOTOR.

BY A. S. LANGSDORF.

[Read before the Engineers' Club of St. Louis, June 3, 1903.*]

DURING the last few years the technical journals have contained frequent accounts of the invention by Mr. Heyland of a form of induction motor which operates at unity power factor. The published articles, however, have been so scattered that it has appeared desirable to the writer to present the subject to the members of this Club in connected form.† The theory of operation of the Heyland motor is, however, so intimately connected with that of the ordinary type that a brief review of the principles of the latter is included as a part of the description of the former.

From the standpoint of mechanical operation, the polyphase induction motor closely resembles the ordinary continuous current shunt motor; for example, in their common tendency towards constant speed with constant impressed e.m.f.; in the improvement of speed regulation effected by reducing armature resistance, and in the feature of a practically constant field at all loads.

In fact, the induction motor may be regarded from one point of view as an evolution of the shunt motor. For it is well known that a D. C. shunt motor preserves the same direction of rotation, irrespective of the direction of the current in the supply circuit; theoretically, therefore, the shunt motor would continue to rotate in

*Manuscript received September 25, 1903.—Secretary, Ass'n of Eng. Socs.

†This paper had been prepared before the writer received a copy of an article on the same subject by Professor C. A. Adams, published in the *Transactions of the American Institute of Electrical Engineers,* Vol. XX, p. 761.

the same direction whether the impressed e.m.f. remains uni-directional or whether it continually reverses; thus, in the limit, if the reversals are rapid and periodic, the motor would be operating on an alternating current supply. Practically, however, this would introduce great complications, and the motor would either spark viciously or refuse to operate at all. For, in the above discussion, it is assumed that currents in the armature and the field circuit reverse simultaneously, which cannot be the case when the impressed e.m.f. is rapidly alternating; here the effect of self-induction, or magneto-electric inertia, disturbs the otherwise simple action. The armature consists of relatively few turns of wire, while the field has very many; the choking action of the armature upon the current is, therefore, very much less than that of the field circuit, so that the current through the armature will alternate nearly in unison with the alternations of the impressed e.m.f., while that through the field will not. As a matter of fact, the field current would lag in phase behind the e.m.f. by nearly a quarter of a period, only reaching a maximum after the armature current has passed its largest value and has fallen to nearly zero. The result is that when the magnetic field, fluctuating in unison with the field current, is a maximum, and, therefore, best suited to produce a torque, there is little or no armature current to react on that field, and hence there is little or no torque. Torque, or turning moment, is proportional to the product of corresponding values of field strength and armature current; in

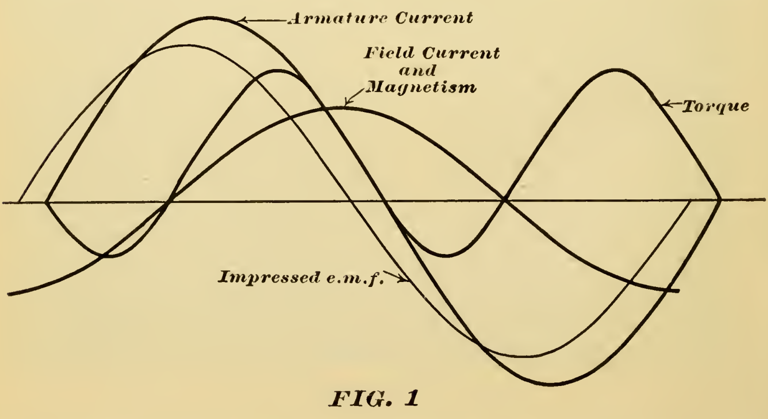


FIG. 1

Fig. 1, curve A represents the variations in this product through one complete cycle of changes, which shows that upon the whole the torque is as much negative as positive.

However, a consideration of this figure shows that this trouble may be cured by supplying the field and armature from independ-

ent circuits, whose alternations are out of phase with respect to each other by a quarter of a period. In Fig. 2, for instance, if

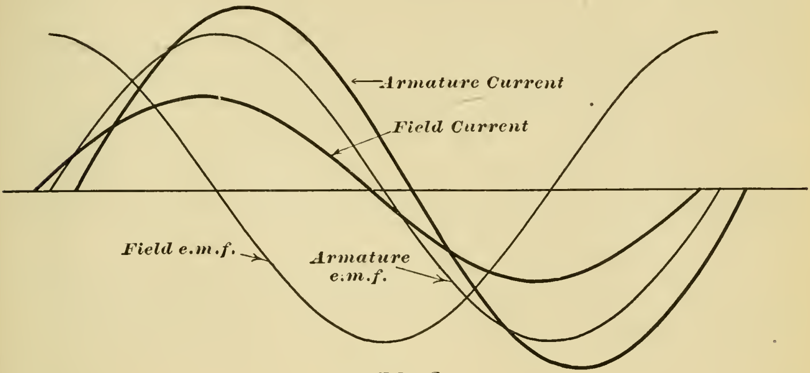


FIG. 2

the alternating e.m.f. impressed upon the field circuit is a quarter of a period ahead of the corresponding armature e.m.f., the resultant field magnetism and armature current will be in phase, or nearly so, thus yielding a torque which is mainly positive in value. This method is, therefore, equivalent to the use of a two-phase supply circuit.

Although the above-outlined plan effects an increased torque and, therefore, a greater output, it still fails to obviate the serious evil of sparking at the commutator. To get around this difficulty it is necessary to take the bull by the horns and do away with the

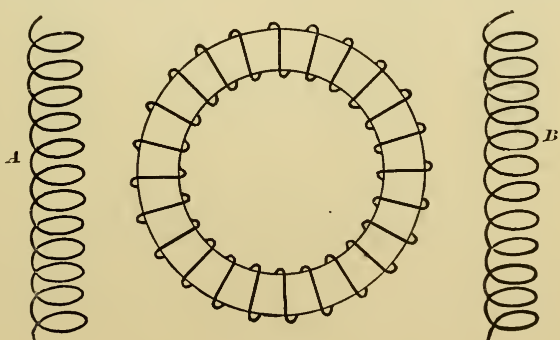


FIG. 3

commutator altogether When this is done, the necessary flow of current in the armature conductors is effected by utilizing the phenomenon of magneto-electric induction familiarly exemplified in the ordinary static transformer. To accomplish this the armature is wound with a closed coil winding, or even with the ordinary

squirrel-cage arrangement of conductors, and is surrounded by a coil, or group of coils, connected to one of the two supply phases. Thus, as in Fig. 3, the armature is surrounded by two windings, one of which, connected to phase A, furnishes the field magnetism; the other, connected to phase B, carries the energy current, which, after the ordinary transformer action, reappears in the armature.

This arrangement is still defective in that it loads the two phases, A and B, unequally, for A carries merely the small magnetizing current, while B carries the much larger current to be transformed into mechanical energy.

The next step in the improvement of the operation must, therefore, be directed towards an equalization of the current consumption in the two phases. This might be done in the following manner:

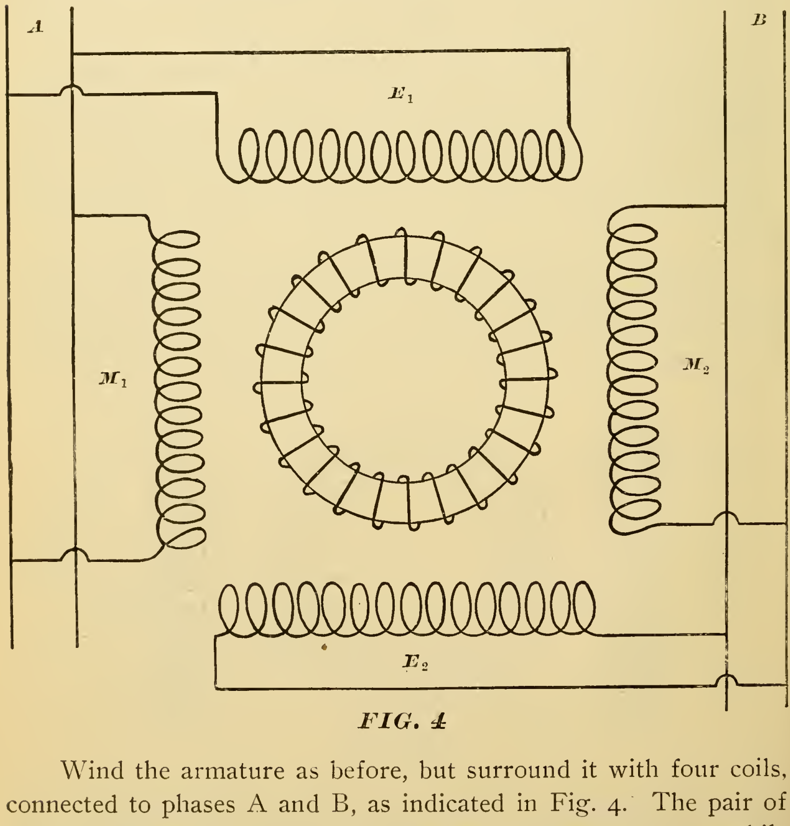


FIG. 4

Wind the armature as before, but surround it with four coils, connected to phases A and B, as indicated in Fig. 4. The pair of windings M_1 and E_2 now act together as in the previous case, while M_2 and E_1 act similarly in all respects, thus dividing the total action between the two pair. Each phase is now equally loaded, since each provides half of the magnetizing and energy currents.

The resultant effect, however, would be precisely the same if the original two coils only were used. For since M_1 and E_1, and similarly M_2 and E_2, are in parallel, they are equivalent to a single coil; if we think of them, therefore, as thus combined, each of the two resultant coils would carry a current whose components are the magnetizing current of one phase and the energy current of the other.

We have now arrived at a point where the ordinary shunt motor has been evolved into the well-known two-phase induction motor; in the process the mechanical characteristics of the former have been retained, while there have been introduced many of the electrical features of the ordinary static transformer. This treatment of the two-phase motor may be as readily extended to include the three-phase type; the difference is only one of degree and not of kind.

It now remains to examine more in detail the various currents and e.m.f.'s encountered in the operation of the polyphase induction motor. The starting point in the investigation is the field magnetism, which is somewhat more complex than the simple, to-and-fro, alternating flux which would exist, for example, in the case illustrated by Figs. 1 and 2. For, instead of a single magnetizing coil, we now have two or more, each of which tends to produce its own independent alternating field; these hypothetical independent fields combine to form the actual field, which is not alternating in space, but rotating at a uniform speed, as can be proved both experimentally and mathematically. The case of the two-phase motor, for instance, is strictly analogous to that of a pendulum subjected to two periodic impulses acting at right angles to one another in space and having a phase difference in time of a quarter period. This resultant rotating field in sweeping around the air-gap cuts across the armature conductors, and thereby induces in them the currents which react upon the field to produce the torque. The armature in its rotation tends to keep pace with the revolving field, *i. e.*, to run in synchronism; truly synchronous speed can never be attained, however, for, if such were the case, a given armature conductor would always be in a field of the same strength, no current could, therefore, be induced, and hence no torque would result. The conductors slip back in consequence by an amount just sufficient to develop the current necessary to carry the load, this slip being nearly proportional to the load, and rarely greater, at least for ordinary service, than 4 or 5 per cent.

This revolving flux is, of course, not of uniform intensity all around the air-gap, but shades off from point to point, forming a

succession of alternate north and south poles whose number depends upon the arrangement of the field coil windings. Any given fixed area in the air-gap is, therefore, threaded by magnetic lines of force passing through it first in one direction, then in the other, just as if the flux at that point was a simple alternating one. A conductor placed there will then have induced in it an alternating e.m.f., which, by the usual law, lags 90°, or a quarter period, behind the inducing flux.

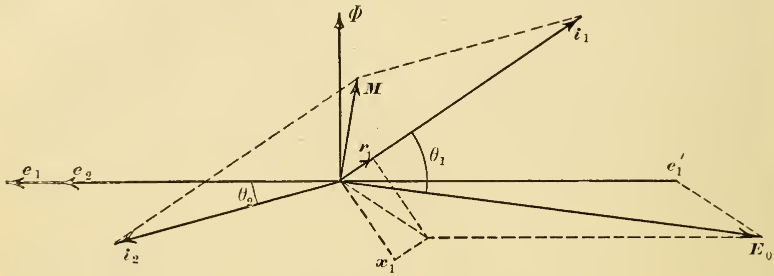


FIG. 5

The inducing flux, or field, is due to the resultant magnetizing actions of the currents in the field coils and in the armature windings. In Fig. 5, OΦ is this resultant field, while OM is the resultant magnetizing force of the field and armature currents, OM being slightly ahead of OΦ in phase due to hysteresis. This flux, as outlined above, induces e.m.f.'s in the field and in the armature, which lag 90° behind it and which are represented by the vectors Oe_1 and Oe_2, respectively. The armature induced e.m.f., Oe_2, produces the armature current, Oi_2, which lags somewhat in phase behind Oe_2 due to self-induction, or magnetic leakage. The primary current, Oi_1, is then found by the use of the parallelogram law of vector combination, since OM must be the resultant of Oi_1 and Oi_2.

The primary impressed e.m.f. must be of such magnitude and phase position that it will overcome (1) the e.m.f., Oe_1, induced by the revolving field, (2) the drop in voltage due to resistance of primary winding, Or_1, and (3) the e.m.f. induced by leakage flux, Ox_1. It is, therefore, equal to OE_0 in the figure, and has the phase position there shown, the construction being obvious.

In this figure, θ_1 is the angle by which the primary current lags behind the impressed e.m.f., and the cosine of this angle is the so-called power factor.

In order to have a high-power factor, therefore, θ_1 must be small. To keep θ_1 as small as possible means a reduction of θ_2 and X_1 to a minimum, or, in other words, a reduction of magnetic leak-

age, the latter being effected by making the air-gap as small as mechanical considerations will permit.

If we confine our attention to a motor in which magnetic leakage and ohmic resistance of primary are negligibly small, the diagram becomes much simplified, as in Fig. 6.

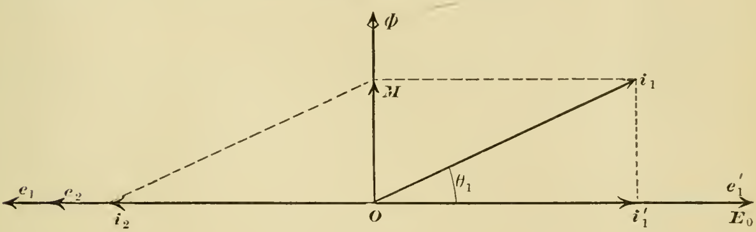


FIG. 6

Here, Oi_2 coincides with Oe_2 in phase, and Or_1 and Ox_1 vanish. The assumption is also made that OM is in phase with OΦ, which is very closely approximated in reality.

The useful power delivered by the motor is, in watts, the product of OE_0 by Oi'_1, the latter being the component of Oi_1 in phase with OE_0; the other component of current $i_1i'_1$, or wattless current, represents no power, but it requires just as much copper section per ampere as the useful current; and, in addition, it has a bad effect upon the voltage regulation of the system supplying the current. It is obvious that if $i_1i'_1$ can be eliminated, the angle θ_1 will become zero, its cosine, and, therefore, the power factor will become unity, and the characteristics of the system will be improved. This is the principal object of the invention of Mr. Heyland, now to be explained.

The heavy lines of Fig. 7 are a reproduction of part of Fig. 6. If θ_1 is to become zero, *i. e.*, Oi_1 shifted to Oi'_1, it is clear that Oi_2

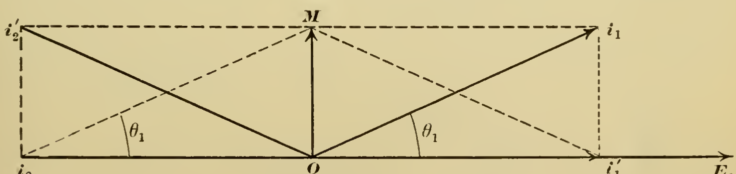


FIG. 7

must be at the same time shifted to Oi'_2, since their resultant must still be OM. This latter change may be effected by introducing into the armature conductors from some external source an auxiliary alternating current whose magnetizing force is represented in magnitude and phase by the line $i_1i'_2$. This result is accomplished by winding the armature with an ordinary closed coil wave winding, such as is

commonly used in D. C. machines, and adding a commutator at one end. At the other end the winding is tapped to collector rings, four of these being provided for two-phase, three for three-phase machines; these rings are then connected to variable resistances. It can thus be seen that the winding is a combination of the ordinary direct current winding and the short circuited or squirrel-cage arrangement so common in induction motors.

The auxiliary compensating current is introduced through the commutator by means of brushes; this current is obtained from the main line supply, and is accordingly an alternating current of the same frequency as that used in the primary or field winding. But the voltage of the supply circuit is in general much too high for driving the relatively small corrective current required, so an additional step-down transformer is required. Moreover, it can be seen that the auxiliary current should be 90° in phase away from that of the voltage of the line, so that, if it were introduced without other precaution, it would be in phase with the e.m.f. This, however, can be corrected by swinging the brushes through which it is introduced through a definite angle, the effect being to shift the phase of the magnetic field due to this current forward by an angle equal to that through which the brushes are swung backward, and vice versa. It need scarcely be added that the field due to this compensating current is a rotative one of the same frequency as that of the main field.

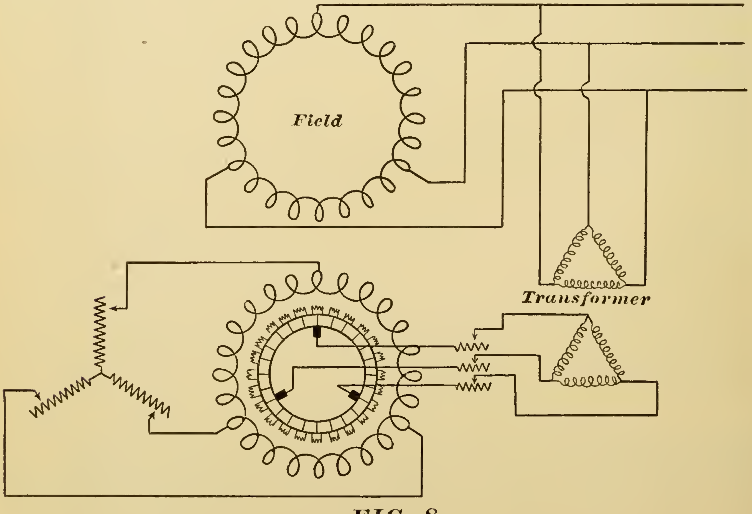


FIG. 8

The completed machine is shown diagrammatically in Fig. 8, for the case of a three-phase supply circuit.

There is another feature, however, which deserves attention. The brushes must, of course, be wide enough to span at least two commutator segments, so that when this happens an element of the winding is short-circuited through the low resistance of the brush. Since this element or coil of the winding carries an alternating current, vicious sparking results, just as in the case of any series wound alternating current motor. To partially overcome this, the gaps between adjacent segments are bridged by resistances of German silver wire, which act as shunts and absorb the energy of the inductive "kick," which would otherwise appear as an arc.

The Heyland motor is, therefore, like an ordinary induction motor, with the addition of a commutator, brushes and a short-circuiting band of relatively high resistance around the commutator. By proper regulation of the position of the brushes and of the voltage applied to them through the small step-down transformer, there may be obtained the advantage of a unity power factor, with its attendant features of greater economy of transmission and improved regulation of the system. By shifting the brushes still farther, a leading current may even be drawn, so that one of the advantageous features of the synchronous motor is added.

On the other hand, some serious disadvantages are introduced, notably the entire removal of the simplicity, which is such a valuable feature of the ordinary induction type. The addition of a commutator does away with the at least strong "talking point" so well known to prospective purchasers of electrical machinery, and prevents the use of this type in the neighborhood of explosive or highly inflammable materials. Again, an adjustment of power factor, which is correct for one load, is not necessarily so for others; consequently, a variable load requires more or less manipulation of the auxiliary brushes and of the rheostat which controls the e.m.f. of the compensating current. However, improvement of the operation of the motor will undoubtedly be effected as the results of experience bring to light the defects of design.

THE COST OF OPEN-HEARTH STEEL AS AFFECTED BY USING BLAST FURNACE GAS IN GAS ENGINES, AND REMARKS ON THE LATEST IMPROVEMENTS.

By Peter Eyermann.

[Read before the Civil Engineers' Club of Cleveland, September 22, 1903.*]

With the enormous development of the industries of the United States was combined the development of all the necessary appliances for the production and transportation of large quantities of iron ore, coal, coke, lime, slag, pig iron and Bessemer and open-hearth steel in all forms and sizes. At the same time all the marvelous installations of the new railway equipments and the fleets of ocean and lake steamers have been growing, and new inventions for the handling of material have astonished the world. The Brown ore-handling plants and gigantic loading cranes, together with the famous system of the three-motor traveling cranes and the scientific Wellman charging machine are wonderful results of a new mechanical science specially founded on electricity.

But, in spite of all these installations, whose original object was labor saving, the price of the open-hearth steel was not cheapened enough to enable it to compete with Bessemer or Thomas blown steel. And with this rapid progress the question of one special kind of steel was growing more important each day; this product, as it is well known to-day, is used more than any other metallurgical product in the world's consumption, and this is the open-hearth steel.

The writer has had the opportunity to study American and European practice, and has always been met by the question how open-hearth steel could be produced at a less cost and in larger quantities. Whenever he has seen the long rows of open-hearth furnaces, especially in the Pittsburg district, his first thought has been: "What would be done in case scrap should be scarce or the price of it should be too high?"

A new style of engineering has within the last few years come into the technical world. This is the important invention, from the other side of the ocean, of operating gas engines directly by blast-furnace gas; but of this scientific and practical question so much has been published within the last few years that it would be a waste of time to dwell long on its advantages.

*Manuscript received October 5, 1903.—Secretary, Ass'n of Eng. Socs.

The following are some important points in reference to gas engines:

There are to-day four types of gas engines especially preferred for the use of blast-furnace gas. The well-known four-cycle single-acting gas engine (Seraing & Deutz) has, as a rule, the following dimensions:*

First. Stroke in inches per indicated horse power, $\frac{3}{8}$ for 100 horse power down to 5-64 for 800 horse power.

Second. Circumference of cylinder in inches per indicated horse power, 11-16 for 100 horse power down to 3-16 for 800 horse power.

Third. Piston area in square inches per indicated horse power, 4 for 100 horse power down to 2.65 for 80 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 25 for 100 horse power down to 15.5 for 800 horse power.

Fifth. Cylinder volume (stroke × piston area) in cubic inches per indicated horse power, 140 to 150 for 100 horse power down to 120 for 800 horse power.

Of double-acting four-cycle engines too few have thus far been put in use to enable us to make a definite statement of relative proportions as in the above case.

In the Oechelhauser type of double-cycle gas engine the joint travel of the two pistons is equal to two diameters of the crank. As a rule, the Oechelhauser has the following dimensions:

First. Stroke in inches per indicated horse power, 7-32 for 200 horse power down to 3-32 for 1000 horse power.

Second. Circumference of cylinder in inches per indicated horse power, $\frac{1}{4}$ for 200 horse power down to $\frac{1}{8}$ for 1000 horse power.

Third. Piston area in square inches per indicated horse power, 1 for 200 horse power to 1000 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 14 for 200 to 1000 horse power.

Fifth. Cylinder volume (stroke × piston area) in cubic inches per indicated horse power, 36 for 200 to 1000 horse power.

This system shows some advantages as compared with the first system.

The proportions of the Körting system, as given below, show some advantage in comparison with similar systems:

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*These figures are calculated from a large number of gas engines.

First. Stroke in inches per indicated horse power, 5-64 for 500 horse power down to 1-16 for 700 horse power.

Second. Circumference of cylinder in inches per indicated horse power, 9-64 average for 600 horse power.

Third. Piston area in square inches per indicated horse power, 0.92 average for 600 horse power.

Fourth. Cylinder area equal to cylindrical surface and added to two piston areas, in square inches per indicated horse power, 7.7 average for 600 horse power.

Fifth. Cylinder volume (stroke $\times$ piston area) in cubic inches per indicated horse power, 44 average for 600 horse power.

The writer is working on a new gas engine, and he expects to reduce considerably the dimensions above given, especially the cylinder area, which he expects to reduce to about 6 square inches, and the cylinder volume to about 25 cubic inches per horse power.

It is to be hoped that the most dangerous installation in all power plants, namely, the steam boiler, will disappear entirely, not alone in the blast furnace, but also, with the improvements in gas producing, in other industrial and manufacturing plants. There remains to be solved only the problem of the right type of gas producer suitable for each quality of coal and producing a power gas free from tar and dust.

On May 7th of last year the writer had the opportunity of reading a paper on this subject before the Iron and Steel Institute in London. Since that time a patent, No. 723,594, has been granted in the United States for this invention, concerning a new process for producing steel.

I will not take up your time to-night by going fully into this subject, but will only state that the most important claim is the use of blast-furnace gas in the open-hearth furnace, either directly or enriched in a special regenerating gas producer. The writer shall feel satisfied if these lines result in discussions or in finding a blast-furnace plant for remodeling.

The writer recently received from one of the most important steel works in the United States a very interesting letter, and which will show how different are the opinions entertained on this subject.

The letter is as follows:

"In looking over your patent I find that it relates principally to the process of producing open-hearth steel, which consists in charging liquid pig iron directly from a blast furnace into an open-hearth furnace and heating this metal first by the combustion of poor blast-furnace gases and finally by the combustion of blast-

furnace gases which have been enriched by passing them through incandescent coke or similar material.

"This process seems to me to be impracticable for various reasons, but it will be sufficient to call your attention to the fact that to produce one ton of open-hearth steel requires the consumption of at least 700 or 800 pounds of good gas coal. Our blast furnace having no gas to spare beyond that made for the heating of the blast and of the production of steam, which later is to be helped out by the use of considerable quantity of steam coal. Besides this, the character of the blast-furnace gases is not such as to produce good effects in an open-hearth furnace. As our blast furnaces have no gas to spare to operate an open-hearth furnace, this alone is sufficient to dismiss the matter from further consideration."

The circumstances as described in this letter are the same in many steel works.

Why not save this wasted gas?

If there are needed 800 pounds or more coal for each ton of open-hearth steel, and if there are necessary, besides, large quantities of steam coal for driving the old-fashioned steam blowing engines; if this is no reason to look for improvements, what other reason could there be?

Influenced by all these considerations, the writer devoted much attention to the study of modern blast-furnace construction—not the metallurgical part, but the structural and mechanical appliances.

In the writer's opinion, the blast furnace of the future will be more important as a producer of gas than as a producer of pig iron, and therefore certain modifications may be introduced in order the better to fulfill the new requirements.

Without entering too closely into details, it may be of interest to refer here to a new form of charging appliance, consisting of a continuously working bucket elevator, which conveys the mixed charge and coke in smaller quantities than is usually the case, and tips it on to the bell. In this manner the distribution of the material in the furnace is the most uniform possible, and consequently great regularity in the evolution of the gases is assured. As a precaution against the unnecessary waste of gas, the throat of the furnace is provided with a bell of the ordinary form, below which is suspended a vertical revolving tube. Within the latter is a screw, which is also capable of independent rotation, down which the charge gradually slides into the furnace, and is thus distributed with perfect evenness. The surface of the screw might be made adjustable in an axial direction, and the revolving motion so arranged

as partially to compress the charge, thus forming a further preventive against the escape of gas. Outside, on the top, are fixed two cylinders in tandem fashion, filled with oil and fitted with plungers, which are suitably connected to the bell by means of levers. By this means the lowering and raising of the bell are effected automatically at certain intervals, the operation being aided only by the weight of the charge accumulated on the bell. This arrangement is an absolutely sure preventive of the escape of gas through the hopper. The drawing off of the gases takes place chiefly at the center of the furnace through a ring-shaped pipe which entirely encircles the vertical charging tube, and, as a precautionary measure against explosion, safety valves, opening outwards, are fitted on the sloping surface of the conical shell forming the cover. Further, it will be seen from the drawing of this "pig iron gas producer" that the main supporting frame of the furnace combines certain features of both German and American practice. In the author's opinion, the American plan of the loose shell is a very excellent one, also the system of water-cooling which extends right through the brickwork to the bosh walls. As regards the tuyeres, the elliptical form of opening for the nozzle (which has proved so efficient in the case of large cupolas) is perhaps the most suitable. It has often come under the author's notice that the rings encircling the furnace bosh, a special feature of American construction, are liable to burst from the strain caused by excessive heating, and it might therefore be an improvement to shape them so as to form reservoirs for cooling water. The whole of the lower framework stands free, and is not walled in by masonry, a plan which is greatly to be preferred, since it prevents the chilling of the furnace hearth by the formation of "bears." The great waste of water in cooling the lower portions of the brickwork, which so frequently occurs in closed masonry and cannot be controlled, is at any rate avoided by this means.

In the following calculation an effort will be made to show how it would be possible to reduce the coal consumption per ton of open-hearth steel, perhaps to 200 pounds or less; and not alone to reduce the coal consumption in the blast-furnace plant for the boilers, but to throw out these coal eaters completely, and to win, besides, enough power to sell it in the form of electricity or in the form of heating furnaces.

It would be very advantageous to have a central gas-improving station, combined with a central gas-cleaning station, but the discussion of this matter in detail would require too much space here.

The new furnace should be called the "Compound Furnace,"

because it combines the experiences of the Bessemer blowing process and those of the open-hearth process. The product may, therefore, be called "Compound Steel."

The following calculation is based on practically known numbers. It is a continuation of the theoretical calculation of Mr. Toldt, read before the Iron and Steel Institute.

It will only be a rough outline sketch, showing what an important plant a blast furnace is:

Calculated self cost for one ton "Compound Steel" produced with the patent process No. 723,594:

First. This combined blast furnace and steel plant uses only modern gas engines. The boiler-house does not exist, and the necessary gas producers, including the blast furnace, are supplied with not only good coke, but all kinds of coke, and, if possible, some kinds of coal. The mixer, the long rows of open hearths, and the separate blowing-engine house are entirely dispensed with. Instead of high-priced scrap, more and cheaper high-grade iron ores and metal directly poured from the blast furnace will be used.

If there is a blast furnace of 500 tons daily capacity, or rather two furnaces of 250 tons each, if there is no other furnace in the neighborhood, an average of 500 tons of coke is used for the production of these 500 tons of pig iron.

$$\frac{500}{24} = \text{nearly 21 tons of pig iron per hour.} \qquad (1)$$

Second. One ton of coke charged into the blast furnace is equal to 4600 cubic meters of gas. This was carefully measured and calculated for the European coke, but for the better American coke a little more gas will be produced, because it is intended to charge more coal and coke into the blast furnace than would be necessary to produce pig iron alone.

In this case the pig-iron producer must also be a gas producer at the same time.

While writing this calculation the writer received from Mr. Uehling a paper, wherein he calculates the quantity of gas for each ton of pig iron at about 10,600 pounds. It can therefore be seen that it will not be very far from a large average to base the following calculation on 5000 cubic meters of blast-furnace gas produced from each ton of coke charged. This is equal to 175,000 cubic feet of gas per hour.

500 tons $\times$ 5000 cubic meters $=$ 2,500,000 cubic meters of gas per day.

$\frac{2,500,000}{24} =$ 105,000 cubic meters of gas per hour, or 3,675,000 cubic feet of gas.

The same result is obtained by multiplying 21 tons by 5000 cubic meters = 105,000 cubic meters of gas per hour. (2)

This quantity of gas is free for use on any kind of work or for selling, but the most important use will be:

Third. For burning the coke in the blast furnace there is blown in, by the blowing engines, for each kilogram of coke, six cubic meters of air per hour; therefore for 21 kilograms of coke there are necessary $21{,}000 \times 6 = 126{,}000$ cubic meters of air per hour, or 2100 cubic meters of air per minute.

Experience shows that nearly 1.3 horse power per cubic meter of pressed air is necessary. This number may be increased to 1.5 horse power for modern plants.

$$2100 \times 1.5 = 3150 \text{ horse power per hour.}$$

For 1 horse power per hour, in a new gas furnace, there are required only 3 cubic meters of gas; or, $\frac{3}{60} = 0.05$ cubic meter of gas per minute = 105 cubic feet of gas per hour. 3150 horse power $\times$ 0.05 cubic meter = 157.5 cubic meters of gas per minute. $157.5 \times 60 = 9450$ cubic meters of gas per hour = 330,750 cubic feet of gas per hour.

The gas above mentioned will be named "Blowing-engine Gas." (3)

Fourth. Careful measurement shows that in existing plants nearly 10 per cent. loss of blast-furnace gas may occur. The loss will be in the pipes at the top, in the dust catcher, by charging ore and coke during the lifting of the bell, etc.; therefore, the next important point will be 10,500 cubic meters of gas per hour = 367,500 cubic feet of gas per hour.

This will be called "Furnace-loss Gas." (4)

Fifth. It would be advisable, not only in the new blast-furnace plants, but also in old plants, to clean all the gas in one central cleaning station. It is known that for each cubic meter of gas to be cleaned there are necessary 0.01 to 0.025 horse power per hour, or for each 1000 cubic feet of gas, 0.3 to 0.75 horse power per hour. One horse power requires 3 cubic meters or 105 cubic feet of gas per hour; therefore, $105{,}000 \times 0.02 = 2100$ horse power per hour, or 2100×6300 cubic meters of gas per hour, or 220,500 cubic feet.

This will be called "Cleaning-engine Gas." (5)

Sixth. It is certainly to be expected that not more than 25 per cent. of the gas will be used for heating the air in the stoves, if all is cleaned. In earlier years this percentage was much greater,

but with the cleaned gas there can surely be obtained 105,000 $\times$ 0.25 = 26,250 cubic meters of gas per hour, or 818,750 cubic feet.

This will be called the "Blast-heating Gas." (6)

Seventh. It is important to observe that under modern conditions this combined steel and blast-furnace plant needs from 100 to 120 horse power for each 100 tons daily capacity for the electric generating plant.

This electricity will be used for all electric-handling machinery and for electric illumination. For 500 tons per day there are needed 120 $\times$ 5 = 600 horse power.

Each horse power consumes 3 cubic meters of gas per hour, or 105 cubic feet; therefore 600 $\times$ 3 = 1800 cubic meters of gas per hour, or 63,000 cubic feet.

This will be called "Electric-generating Gas." (7)

Eighth. Directly in combination with the blast-furnace plant should be the compound steel furnace. In an open-hearth furnace of the general style the average for each ton of steel is 300 kilograms of good coal, or nearly 675 pounds per ton. These 675 pounds are specially needed where many steel ingots are poured. This quantity of coal is equal to 1500 cubic meters of producer gas.

There are 21 tons of pig iron to be converted into steel each hour. For this there are used 21 $\times$ 1500 = 31,500 cubic meters of producer gas.

The difference of units between the producer gas and the gas from the blast furnace is only from 100 to 200 calories per cubic meter, or 10 to 20 B. T. U. per cubic foot.

It will, therefore, be sufficient for this rough calculation to accept this number also for the compound furnace, as it is intended to work only three-fourths or two-thirds of the whole heating time with blast-furnace gas directly. During other parts of the heating time there will be used coke gas from the attached producer, mixed with improved blast-furnace gas. The latter is better than any producer gas, because it has up to 1500 calories per cubic meter, or 170 B. T. U. per cubic foot; therefore, 31,500 $\times$ $\frac{2}{3}$ = 21,000 cubic meters, or 735,000 cubic feet of gas are used in the compound furnace.

This may be called "Compound-steel Gas." (8)

Ninth. One of the most important ideas in this patent is the use of the blast of the blast furnace directly in the open-hearth furnace.

With this air the first rough fining of the metal should be done; therefore, a certain horse power is more necessary for driving blowing engines than is necessary for the blast-furnace plant alone.

This refining blast can be taken directly from the main pipe, hot or cold.

Finishing, for example, 20 tons of steel in a general Bessemer or Thomas plant, there are needed nearly 1000 to 1200 cubic meters of air.

If, as in this patent, only a rough fining is necessary, it will probably not be wrong to say 300 to 500 cubic meters for these 20 tons, or 15 to 25 cubic meters per ton of steel.

Taking 25 cubic meters, and remembering that there are 21 tons per hour to the fining, this will be:

$$21 \times 25 = 525 \text{ cubic meters of blast.}$$

For each cubic meter there are necessary from 1 to $1\frac{1}{2}$ horse power per hour, if the pressure above stated is sufficient. Each horse power needs again 3 cubic meters of gas in the gas engine; therefore, $525 \times 3 \times 1.5 = 1575 \times 1.5 = 2362$ cubic meters, or 82,690 cubic feet of gas.

This will be called "Fining-blast Gas." (9)

Tenth. Under "eighth" we obtained 31,500 cubic meters of gas. Of this only 21,000 have been used directly in the furnace, there remaining 10,500 cubic meters for improving purposes; but it is possible that only 6000 cubic meters are needed for regenerating in the coke stoves.

Some blast-furnace gas can also be used for heating the ladles for burning fireproof materials, besides some loss in the valves, dampers and pipes, which will occur.

Together with the 6000 cubic meters, we may calculate here 10,500 cubic meters, or 367,500 cubic feet, of gas per hour.

This will be called "Steel-loss Gas." (10)

Eleventh. To complete this outline of the modern steel plant, it is important to state that there are in use other methods of converting by-product into money:

(a) The use of coke-oven gas, in the common way or in the compound-steel plant.

(b) The manufacture of bricks from the blast-furnace slag.

(c) The installation of a burning and milling factory for Portland cement.

To calculate these economies here would require too much space, but we may estimate them at an average of $1 to $2 per ton of pig iron, according to circumstances. (11)

Twelfth. The future of such a steel plant does not depend upon the quality of the iron ore as do the Bessemer plants of to-day. If no high-grade silicon pig iron is to be obtained, then high-phos-

phorus iron is also convenient. All grades of pig iron and ore can be used directly in this "Compound-furnace Plant," and scrap only when it is very cheap.

If the local conditions are favorable, it may also be possible to produce basic slag. This by-product can be sold as a fertilizer, saving from 50 cents to $1 per ton of steel. (12)

Thirteenth. The following table gives a clear idea of the different uses of gas per hour.

Paragraphs 11 and 12 may be neglected, as they give only practical results, which have no influence in the following gas calculation:

(3) Blowing-engine gas, 9450 cubic meters, or 330,750 cubic feet.

(4) Furnace-loss gas, 10,500 cubic meters, or 367,500 cubic feet.

(5) Cleaning-engine gas, 6300 cubic meters, or 220,500 cubic feet.

(6) Blast-heating gas, 26,250 cubic meters, or 918,750 cubic feet.

(7) Electric-generating gas, 1800 cubic meters, or 63,000 cubic feet.

(8) Compound-steel gas, 21,000 cubic meters, or 735,000 cubic feet.

(9) Fining-blast gas, 2362 cubic meters, or 82,610 cubic feet.

(10) Steel-loss gas, 10,500 cubic meters, or 367,500 cubic feet.

Per hour, 88,162 cubic meters, or 3,085,690 cubic feet. (13)

Fourteenth. The blast furnace has 105,000 cubic meters, or 3,673,000 cubic feet of gas free to sell per hour, which, after deducting 88,162 cubic meters, or 3,085,690 cubic feet, of gas, leaves 16,838 cubic meters, or 589,310 cubic feet, per hour. (14)

Fifteenth. The best way to sell power to-day is in the form of electric current. It can be obtained directly from gas engines. Each horse power requires 3 cubic meters or 105 cubic feet, of gas per hour.

$$\frac{16,838}{3} = 5600 \text{ horse power.}$$

In proportion to this electricity which is produced from coal in steam engines it certainly will not be too high to sell this furnace electricity for lighting purposes at 2 cents per kilowatt, or $5600 \times 0.746 = 4170$ kilowatts.

Now, assuming that in practical use only one-half of this power could be obtained,

$$\frac{4170 \times 2}{2} = 4170 \text{ cents, or } \$41.70 \text{ per hour.}$$

In each hour 21 tons of steel are produced; therefore there is a profit on 1 ton of steel of nearly $2 by selling electricity. (15)

Sixteenth. The superintendent of the blast-furnace plant would not give his gas to the steel plant for nothing. As seen above, each cubic meter of gas is worth 0.25 cent if sold in the form of electricity.

The steel plant needs the above three numbers, 21,000 ÷ 10,500 ÷ 2362 = 33,862 cubic meters of gas per hour.

It would probably only be possible under extraordinary circumstances to sell this gas at the same price as electric light; therefore, it would sometimes be better to sell it in large quantities in the form of electric power directly. In this case only 0.5 to 1 cent per kilowatt can be obtained.

This would be another theoretical profit of $\frac{33{,}800}{3} = 11{,}200$ horse power, or 8400 kilowatts. $8400 \times 1 = 8400$ cents; or, divided by 21 tons, = $4 per ton of pig iron; or, again, taking only half of this result, there will be a profit of $2 per ton of pig iron. (16)

Seventeenth. The blast-furnace plant can sell this gas cheaper if no electric generating engines are necessary; if sold as gas, it is to be noted that the heat efficiency of the blast-furnace gas is lower than that of the producer gas.

It is stated above that 1 cubic meter of gas, sold in the form of power, is worth 0.25 cent; but, when sold as gas directly, the writer will say only 0.1 cent up to 0.125 cent per cubic meter.

33,862 cubic meters, or 1,185,190 cubic feet, give, therefore, $33.862, or $42.50 profit per hour for the blast furnace.

In each hour 21 tons are produced; therefore, there is a profit of from $1.60 to $2 per ton of pig-iron. (17)

Eighteenth. Before closing this calculation it will be interesting to compare the cost of operating a European 15-ton open-hearth furnace, using good German coal:

(a) Coal for gas in the producers, including small quantities of steam coal—480 pfennige, or 120 cents, per ton.

(b) Loss of combustion of the hearth—500 pfennige, or 125 cents, per ton.

(c) Firebrick, limestone, dolomite—200 pfennige, or 50 cents, per ton.

(d) Repairing cranes, etc.—80 pfennige, or 20 cents, per ton.

(e) Molds, bottom plates—180 pfennige, or 45 cents, per ton.

(f) Fluxes and special iron—40 pfennige, or 10 cents, per ton.

(g) Wear of the installation—300 pfennige, or 75 cents, per ton.

(h) Salaries—440 pfennige, or 110 cents, per ton.

Total—2220 pfennige, or 555 cents, per ton.

The cost of converting 1 ton of charges in open-hearth steel is, therefore, $5.55. (18)

Nineteenth. In a furnace of 200 tons capacity, and working continuously, the approximate cost of 1 ton of steel ingots will be only 1300 pfennige or less. (See paper read before the Iron and Steel Institute, London, May 7, 1902.) It will be interesting to compare these points with the following calculation.

Here it must be said that it was proposed to use the 200-ton furnace some years before, without the knowledge that Jones & Laughlins, of Pittsburg, have been erecting, in the meantime, a furnace of this capacity.

It is clear that in the English patent the proposition was made to combine the new Talbot process with this blast-furnace gas process. It is to be hoped that such a combination may have good results.

(a) Coke and coal for improving blast-furnace gas and producing coke gas—160 pfennige, or 40 cents, per ton.

(b) Loss of the hearth—320 pfennige, or 80 cents, per ton.

(c) Firebrick, lime, dolomite, magnesite—140 pfennige, or 35 cents, per ton.

(d) Repairs—60 pfennige, or 15 cents, per ton.

(e) Molds, bottom plates—160 pfennige, or 40 cents, per ton.

(f) Fluxes and special iron—80 pfennige, or 20 cents, per ton.

(g) Wear of the installation—200 pfennige, or 50 cents, per ton.

(h) Salaries—100 pfennige, or 25 cents, per ton.

Total—1220 pfennige, or 305 cents, per ton.

The difference is 1000 pfennige, or $2.50 per ton of converted steel.

The iron ore is here calculated with the charge, and not in the way adopted by Mr. Talbot.

Referring to "b" and "e," both can be reduced under certain circumstances.

The cost of producing 1 ton of steel would be still lower if a basic fertilizer slag could be obtained. (19)

Twentieth. The cost for one ton of pig iron, produced from a modern blast-furnace plant, situated in the neighborhood of a large city, able to sell all its power in electricity and equipped only with gas engines, would be very low. By adding together the figures given in paragraphs 15 and 16, we find that there would be a profit of $4 on each ton of pig iron; but under certain conditions only $2 profit. This profit can be nearly guaranteed to-day wherever an old-fashioned blast-furnace and steel plant is remodeled for this purpose. (20)

Twenty-first. The cost of producing 1 ton of "Compound Steel" would be:

(a)	Gas of the blast furnace..........	$1.60
(b)	Converting cost	3.05
	Total	$4.65

To the above is to be added the cost of 1 ton of the charge (including the pig iron), and, as already shown, this is very low.

Excluding case 20, but referring to paragraphs 11, 12 and 15, it is certainly possible to make pig iron for $2 to $4 less per ton than it costs to-day. (21)

This calculation shows that open-hearth or compound steel can be produced, under good conditions, just as cheaply as pig iron to-day, or still cheaper in connection with the modern gas engine.

OBITUARY.

August H. Schierholz.

Member of the Technical Society of the Pacific Coast.

August H. Schierholz, a member of the Technical Society of the Pacific Coast, came to an untimely end through a street-car accident in San Francisco on September 2, 1902.

In this able engineer and thorough gentleman the Society has lost one of its most valued members, one who, in his extreme modesty, preferred to listen and absorb rather than to come forward and speak of himself and of his valuable experiences in lines that should have made him prominent. He was justly entitled to prominence.

Born on July 7, 1839, in Enger, Westphalia, Prussia, he received in his youth that thorough education and technical training which enabled him to follow successfully the practical career in store for him. After serving his one year in the Prussian army and participating as a volunteer in the war between Prussia and Denmark, a war that resulted in the final incorporation of Schleswig-Holstein into the kingdom of Prussia, he came to the United States, like many of the young and energetic men of his time, and made his first stay in Chicago.

It was in 1872 that he came to California, and soon after his arrival he was engaged by the Risdon Iron Works, and with that firm he remained almost constantly up to the time of the unfortunate accident that removed him from a sphere of usefulness to which he had devoted all these years and the best part of his manhood.

Some of the prominent works with which he has been connected may be named here to show the versatility of the man's genius:

The erection of a sawmill and plant on the Uintah Indian Reservation in Utah, 200 miles from Salt Lake City.

The reconstruction of the machinery for the Tiger and the Poorman mines in Idaho.

The various machinery and mechanical devices for the exploitation of the Comstock Lode are in great part the result of his untiring activity.

Many of the enterprises connected directly with the welfare and prosperity of the State, such as the water supply of the city of San Francisco, the agencies for navigating the coast and harbors of the Pacific, the development of the large resources in water power made available through electric transmission, have had, at some time

or other, the benefit of his practical sense, particularly in adapting them to existing conditions and circumstances, which has always called for men of superior ability and energy in this remote part of the world.

The Cane-Sugar Mill of the Honolulu Plantation, Oahu, Hawaiian Islands, and the Beet-Sugar Factory at Salinas, Cal., the largest and best equipped anywhere, were built under his mechanical supervision.

Unobtrusive manners and exceeding modesty were the principal characteristics of this remarkable man. These qualities alone prevented him from acquiring a very marked prominence in this community and in our Society. Many a younger member of our calling has had the benefit of his instruction while he was chief draughtsman for the Risdon Iron Works, and will remember with gratitude his readiness to impart whatever was required of his large store of experience.

His friendship was undemonstrative, but lasting. His preference, after the toil of the day, was for quiet enjoyment of nature and home; the latter tendency was manifest in the fact that he seldom went to any of his distant fields of labor without the thoughtful companion of his life—the wife who survives him.

One well qualified to judge this man, one who has been in professional contact with him for many years, who well knows the true value of the character and ability of the late August H. Schierholz, our Past President George W. Dickie, writes of him as follows:

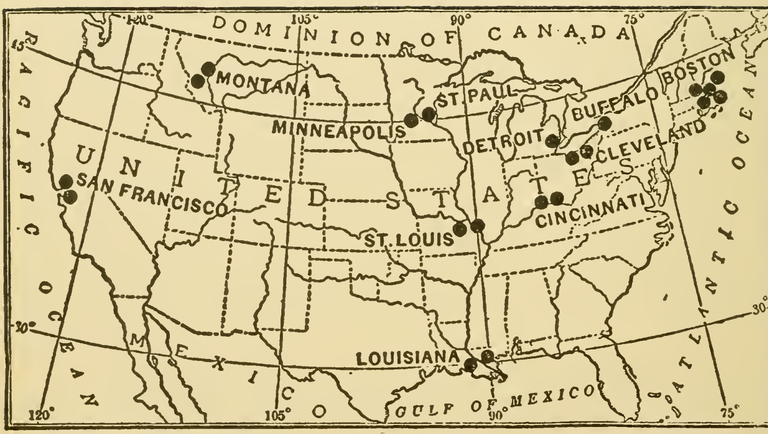
"Mr. Schierholz was one of those rare characters who had the ability to keep self in the background and devote all his power of mind to reaching the best solution of the problem he had in hand at the time. Only those who had a close, working acquaintance with this modest draughtsman could form any estimate of his work as a man and his great ability as a designer of mechanical structures. He had a rare faculty of seeing beneath the surface of the paper he was working on, and a simple elevation prepared by this talented man would convey all the information usually given by plans, elevations and numerous sections. He could give in a few hours one view of a complicated machine, showing all the parts in their relative positions for estimating purposes, which, when detailed out, would show that every part had its proper clearance, enabling the original design to be carried out as shown by his first picture of it. This faculty, so rare even in accomplished draughtsmen, gave to Mr. Schierholz's work a peculiar value, which enabled those fortunate enough to secure his services to present plans and

specifications of the most complicated work in a miraculously short time. And yet, with this faculty so valuable to an engineering business, his extreme modesty prevented him from making any true estimate of his own work.

"The writer had an intimate association with Mr. Schierholz for about twelve years, which was severed twenty years ago. He has, however, during these twenty years held Mr. Schierholz up, both to himself and to others, as a model draughtsman, wise in his profession and admirable in his character."

The Technical Society mourns the loss of this member and adds this as a fitting memorial to a man who, fully identified with the Pacific Coast, will not be forgotten, for his impression has been made and will be found far and wide wherever Mr. Schierholz has been and where his genius has found expression.

A. d'Erlach,
Committee.



DOMINION OF CANADA
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DETROIT
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BOSTON
CLEVELAND
UNITED STATES
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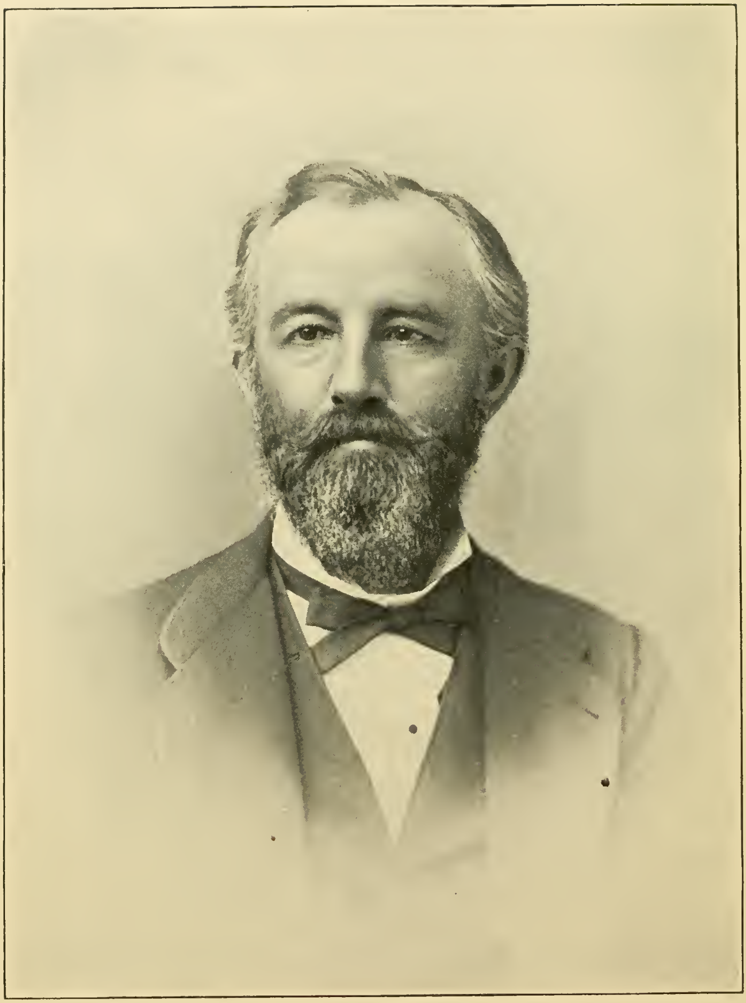

GEORGE FREDERICK ALLARDT.

Civil Engineer. Late Member Technical Society of the Pacific Coast.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

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GAS.

BY THOMAS D. MILLER, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, April 3, 1903.*]

THE Century Dictionary contains the following biographical note:

"Murdock, William. Born at Auchinleck, Ayrshire, August 21, 1754. Died at Birmingham, November 15, 1839. A Scotch inventor. He entered the works of Boulton & Watts, Birmingham, in 1777, and in 1795 made the first practical use of illuminating gas. He also invented the oscillating steam engine."

From the day that Murdock discovered coal gas and applied it to illuminating purposes, over a century ago to the present time, there has been a steady improvement in the methods and appliances for the manufacture, distribution, sale and use of illuminating gas. After Murdock's discovery, inventors were at work perfecting the furnaces to supply the heat to distil the gas from the coal; means for the extraction of the coal tar and other impurities had to be devised; and the storage and distribution of the gas through pipes required great ingenuity at that time. The measurement of the gas was a perplexing problem, and the burners for its consumption absorbed considerable attention then and have done so to this day.

The first complete gas works built was fundamentally the same as the coal-gas works of to-day. The coal was placed in retorts and the gas was taken off through hydraulic mains, passing through a scrubber, a condenser and a purifier of some character or other.

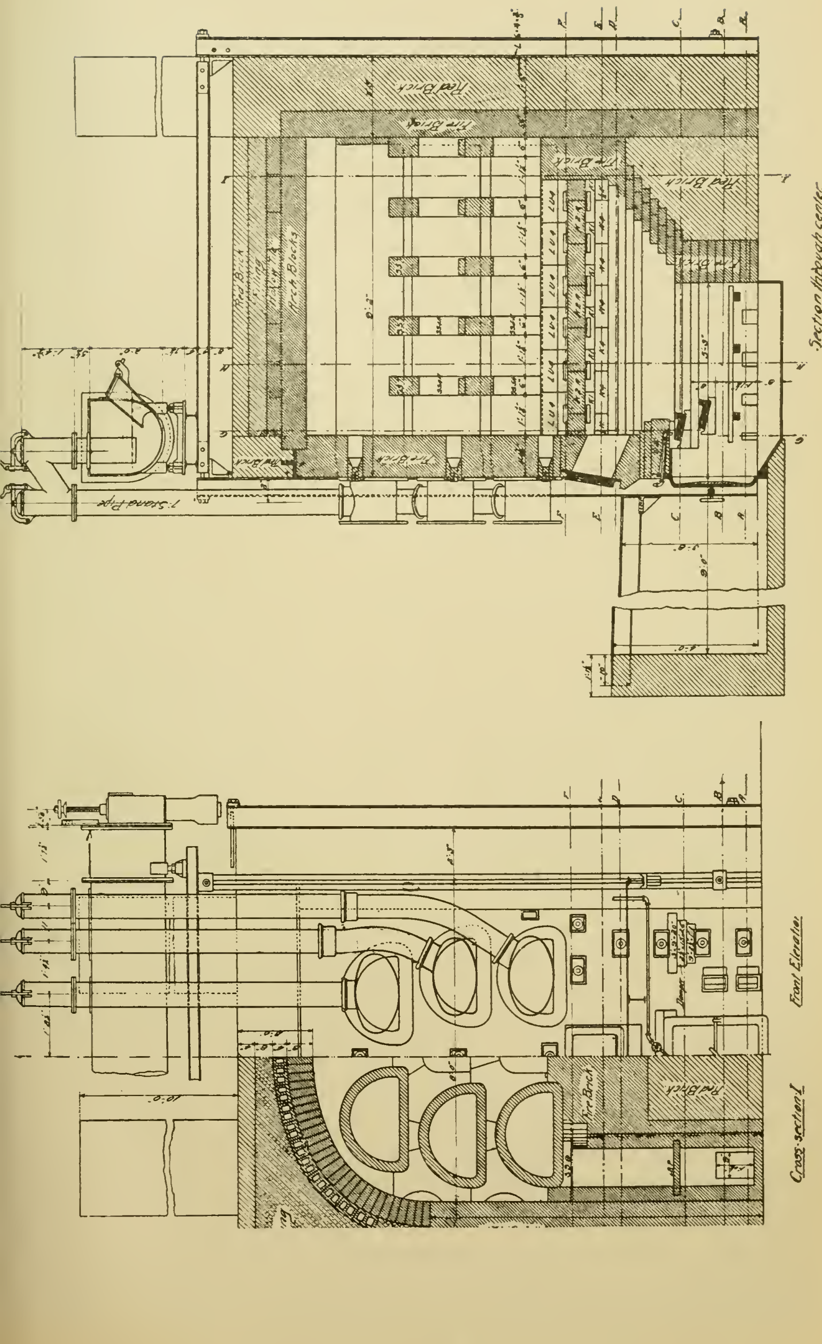
*Manuscript received October 13, 1903.—Secretary, Ass'n of Eng. Socs.

The storage holder caused considerable uneasiness when first erected, and the Common Council passed ordinances requiring that the "gasometer" should be inclosed in a substantial brick building, so that in case of an explosion the community would be protected from injury by the building. The honorable members of the Council were surprised and incredulous when informed that the contents of the gasometer could not explode until mixed with air, and they were dumbfounded when a pick point was driven through the side of the holder and a torch applied to the hole resulted in nothing more than the emission of a flame from the opening. Even to-day thousands of our citizens hold much these same beliefs.

COAL GAS.

The apparatus for the manufacture of coal gas consists of one or more benches, consisting of an arch or oven, constructed of fire-brick, at the bottom of which is a furnace, the upper part of the arch being filled with retorts made of clay with cast-iron mouthpieces. These mouthpieces extend beyond the brick wall which closes the end of the arch, and have lids which are readily removed. Attached to each mouthpiece is a cast-iron pipe for conducting the gas away from the retort. These riser pipes pass up to the top of the bench and down into what is known as the hydraulic main. This hydraulic main is in effect a water seal or valve, and gets its name from the fact that it is partially filled with water, which water rises up above the bottom of the gas or dip pipes passing down into the main. When the gas is being generated in the retort it forces its way up through the water. In doing so the water condenses a portion of the tar that is in the gas and the tar is drained off from the bottom of the hydraulic main. This water also absorbs a portion of the ammonia that is present in the gas as an impurity. The special purpose of this hydraulic main, however, is to automatically prevent the gas from going back from the holder into the retort, when the mouthpiece is open for the purpose of drawing the coke or charging the retorts with coal, acting much after the fashion of a check valve.

The pressure in the retorts necessary to force the gas through the water in the hydraulic main and the several pieces of purifying apparatus into the holder is so great that there is a considerable loss in the yield of gas, unless relieved by the introduction of a suction pump, known as an exhauster. This exhauster is usually connected up in the line of the main gas off-take pipe immediately beyond the retorts. The exhauster is so constructed and the supply so regulated that any desired pressure can be kept in the hydraulic mains



SEMI-RECUPERATOR BENCH OF SIX RETORTS.

at all times. After the gas has been drawn out by and has passed the exhauster it is put through a condenser for cooling, in which a great deal of the tarry globules or vapor is thrown down and drains off to the tar well. Then it usually passes through some further form of tar extractor or washer, where the remaining particles of tar should be removed. Thence it passes through the scrubber, where it is brought in contact with water, which absorbs the remaining portion of ammonia in the gas. After the gas has left the scrubber it should need but one more purification, and that is the removal of the sulphur compounds which usually appear in the form of sulphuretted hydrogen and bisulphide of carbon. These sulphur compounds were formerly removed by quicklime moistened and placed upon trays in large cast-iron boxes, the gas being forced through this lime. In later years the lime has been practically abandoned and replaced by what is known as "iron sponge," a preparation of some form of oxide of iron. This oxide of iron takes up the sulphuretted hydrogen, forming sulphide of iron. This sulphide of iron reoxidizes on being exposed to the air, depositing fine crystals of sulphur and reforming as oxide of iron, and can therefore be used over and over until it becomes excessively charged with sulphur.

A small percentage of free sulphur is very desirable for removing traces of bisulphide of carbon in gas, as the sulphur has a very decided affinity for bisulphide of carbon, and mechanically holds it behind.

These purifying materials were formerly regarded as excellent remedies for whooping cough, and many an old gas man will recall incidents of the hundreds of children he has treated for this complaint.

When the gas leaves the lime or oxide boxes, it is entirely purified and ready for use, if the work has been properly done. It is then passed through the station meter or meçhanical accountant, which shows the amount of gas made, and is then stored in the holder, whence it is distributed through the mains, services and housepipes of the community to the burners where it is consumed.

In passing from the mains to the housepipes the gas once more is measured by a mechanical accountant; that is, by the usual house or consumer's meter.

The coal best adapted to the manufacture of coal gas is a bituminous coal, containing from 20 to 40 per cent. of volatile matter, rich in hydrocarbons, and is typified by the following analy-

sis of one of the best grades of Pittsburg gas coal, which shows as follows:

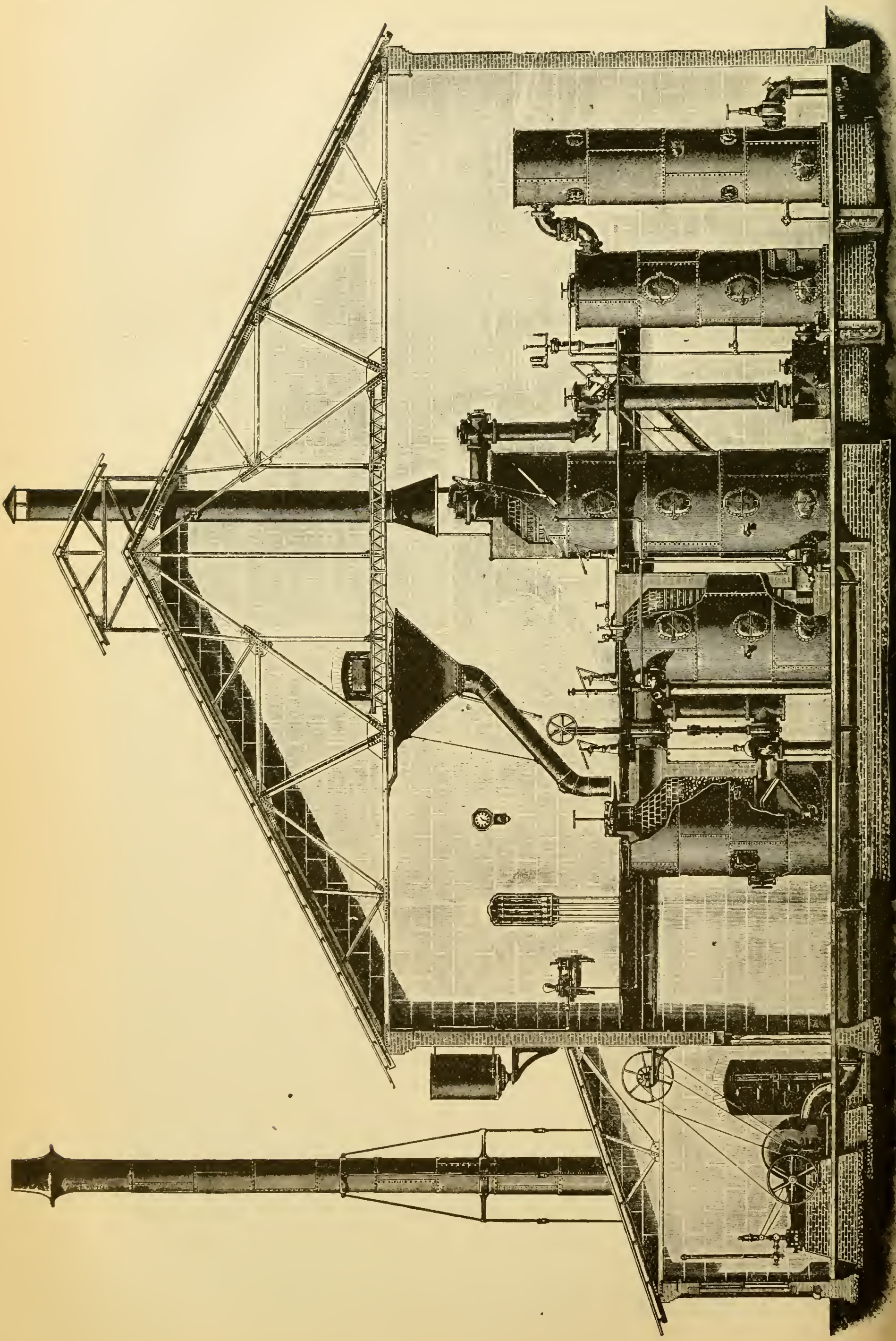
Moisture	1.26
Volatile matter	36.14
Fixed carbon	59.70
Ash	2.90
Sulphur	.99

In this analysis the sulphur was separately determined.

WATER GAS.

Professor T. S. C. Lowe was employed by the Federal Government, during the Civil War, in the balloon service of the army, and in his experiments to produce large quantities of hydrogen for use in balloons he invented, as the result of his experiments, what is commonly known as the "water-gas" process. This process is substantially the disintegration of steam by a bed of superheated carbon, producing carbonic oxide and hydrogen. The blue or non-illuminating gas thus produced possesses very inferior heating qualities, being only about 300 B. T. U. to the cubic foot, while illuminating gas possesses from 650 to 750 B. T. U. to the cubic foot; but when the vapors of oil are introduced, there is produced the commercial carburetted water gas of to-day.

The process of the manufacture of the water gas differs from that of the coal gas only in the method of generating. The water-gas apparatus consists of a generator, carburettor and superheater. The generator is a large vessel made of sheet steel, lined with fire brick with grate bars at the bottom. The carburettor is a similar shell lined with fire brick and filled with fire brick set loosely to form checker work. The superheater is also a steel shell, precisely similar to the carburettor, but longer, and is lined with fire brick and filled with checker brick, the same as the carburettor. These shells stand on end, each one close to the other. The generator is connected to the carburettor at the top by a pipe lined with fire brick. The carburettor is connected to the superheater at the bottom by a similar pipe lined with fire brick. On the top of the superheater is a large valve, known as the "stack valve," and leading out from the side of this stack valve is the off-take pipe, which passes down to a washer or seal, corresponding precisely to the hydraulic main or water valve in the coal-gas process. After the gas has passed this wash-box or seal, the purification process is precisely the same as in the case of coal gas. The method of manufacturing water gas is as follows: the generator is filled with coke or hard coal and ignited

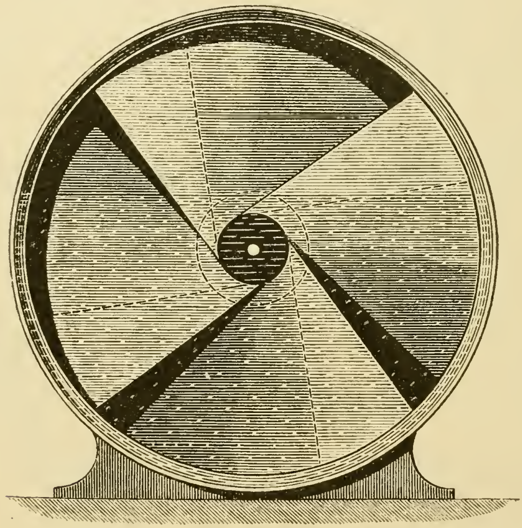


at the bottom. A fan or blower of proper size, operated by an engine, furnishes a blast which is controlled by a valve at the bottom of the generator. The blast being admitted under the grate bars, passes up through the fuel bed and brings up the heat of the coke or coal, at the same time making a producer gas which passes into the top of the carburettor, where another blast is admitted, igniting this producer gas, causing a secondary combustion that results in bringing up the temperature of the checker brick in the carburettor. Some of the producer gas passes down through the carburettor into the bottom of the superheater, where another blast is admitted, igniting this producer gas, causing further combustion and bringing up the temperature of the checker brick in the superheater. The "blow" is conducted for a time sufficient to bring up the temperature in the generator to from 1900 to 2000 degrees, and the checker brick of carburettor and superheater to a degree varying according to the quality and kind of oil to be used; at any rate, to a red heat. When this proper temperature has been obtained throughout the apparatus, the air blast is shut off, the stack or outlet valve on the superheater is closed and steam is admitted under the grate bars of the generator and passed up through the bed of superheated carbon and is thereby dissociated, the reaction in the incandescent coal or carbon producing hydrogen and carbonic oxide, that is, "water gas" commonly known as "blue gas." This water gas passes through the pipe connection into the carburettor, where it comes in contact with an oil spray from an injecting nozzle, which distributes oil at the top on the red-hot checker brick, and thus generates oil vapor, and this oil vapor, mingling with the water gas, passes down through the checker brick of the carburettor into the bottom of the superheater and up through the superheater, during which passage the oil vapor is changed to a fixed gas. The resulting oil-water gas is then passed out of the off-take pipe down through the washbox and out through the purifying apparatus to the holder. In the production of carburetted water gas no ammonia is made. In practice, the air blast is kept on from five to seven minutes, and this process is continued throughout the day, or week, or month, or year, the only interruptions being for coaling up, clinkering and repairing.

In the manufacture of water gas the fuel used is either coke or anthracite coal. No water-gas process has yet been successfully devised by which soft or bituminous coal can be used. Several of these processes have been attempted, and in a number of cases plants have been installed, but after being operated for a few years,

in most cases they have been converted into some standard form of water-gas apparatus.

In former days the demand for high candle power was the cause of the marketing of large quantities of cannel coal for gas making, and the gas was made by mixing a certain percentage of cannel coal in with the gas coal. After the introduction of the carburetted water gas, a great many plants abandoned the use of the cannel coal and installed auxiliary water-gas plants, making a rich water gas, to be mixed with coal gas, and thereby bringing up the candle power of the mixed gas to the desired standard.

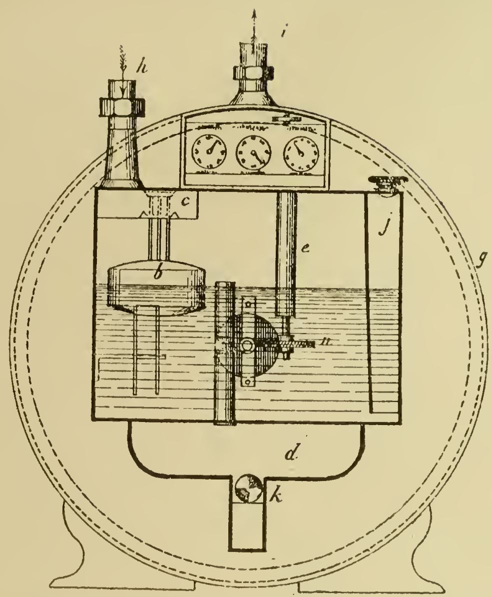


Wet Meter, Showing Drum from Outlet End.

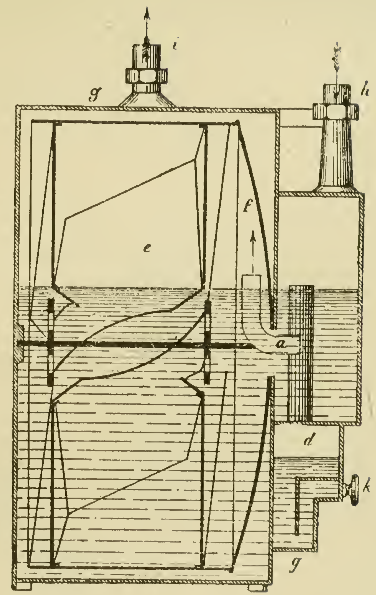
METERS.

One of the first gas meters invented was made of bladders, which were so arranged that one bladder would be filled with gas from the holder, and in expanding would force the gas out from another one already filled, and a valve system would shift the responsibility from one to the other, and thereby furnish a steady supply. This shifting of the valves by suitable clockwork registered the number of times each bladder had filled and emptied. In this way the amount of gas passed could be obtained. These bladders, owing to the properties of gas, soon became dried and cracked, and were finally abandoned for improved devices. The wet and dry meters were the final results of experiments on these lines.

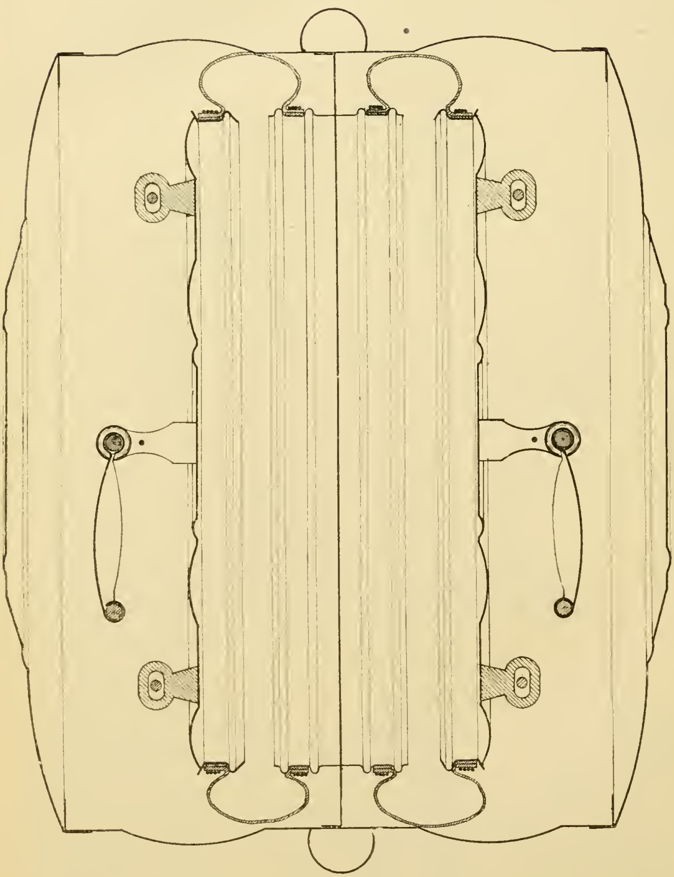
The wet meter consists of a miniature overshot water wheel partially submerged in water and revolving on a shaft. This wheel



WET METER, SHOWING WATER-LEVEL FLOAT *b* AND GEAR SHAFT *e* CONNECTION TO DIAL.

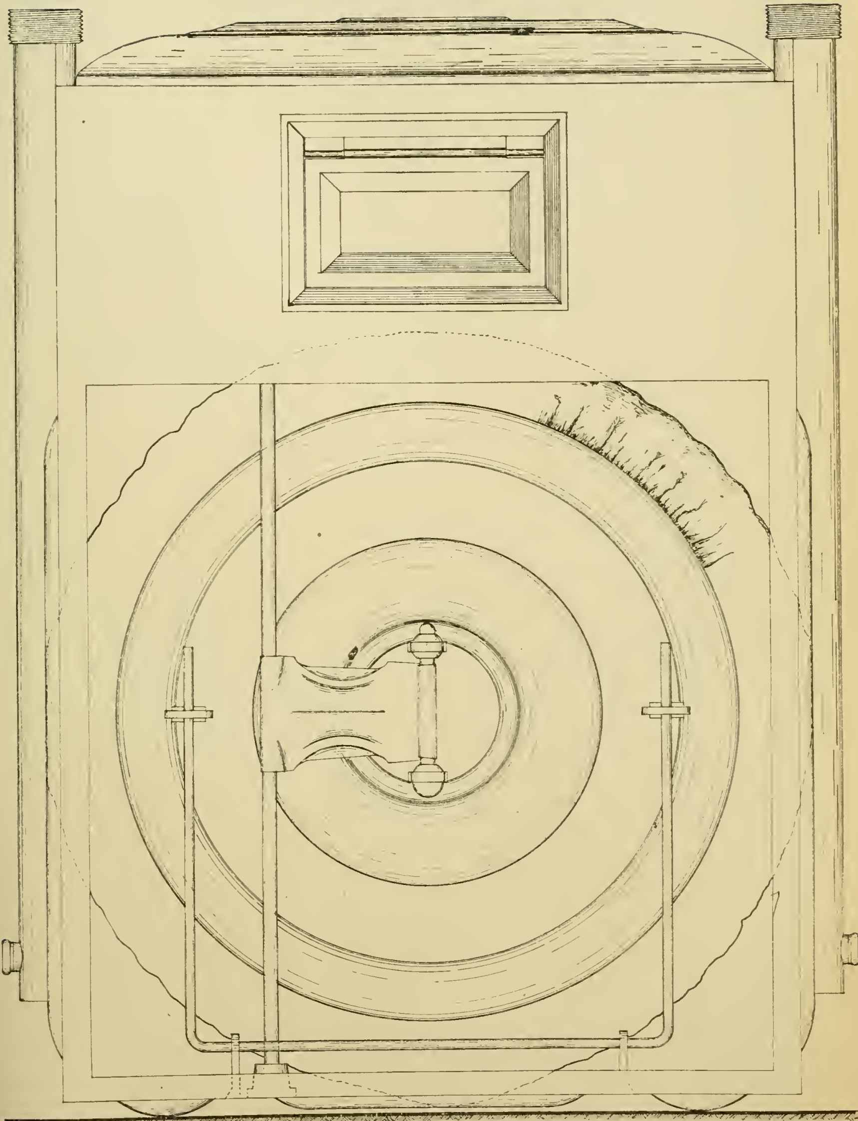


SECTION THROUGH WET METER, SHOWING DRY WELL *a* INLET FOR GAS.

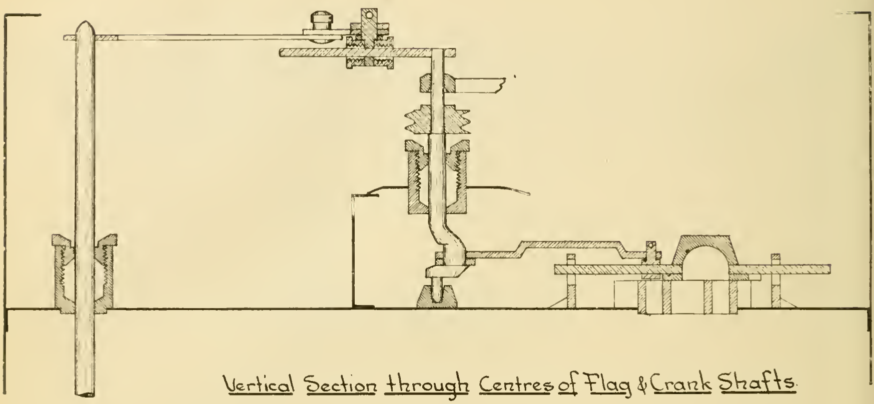


Horizontal Section through Centre of Diaphrams.

Dry Meter.

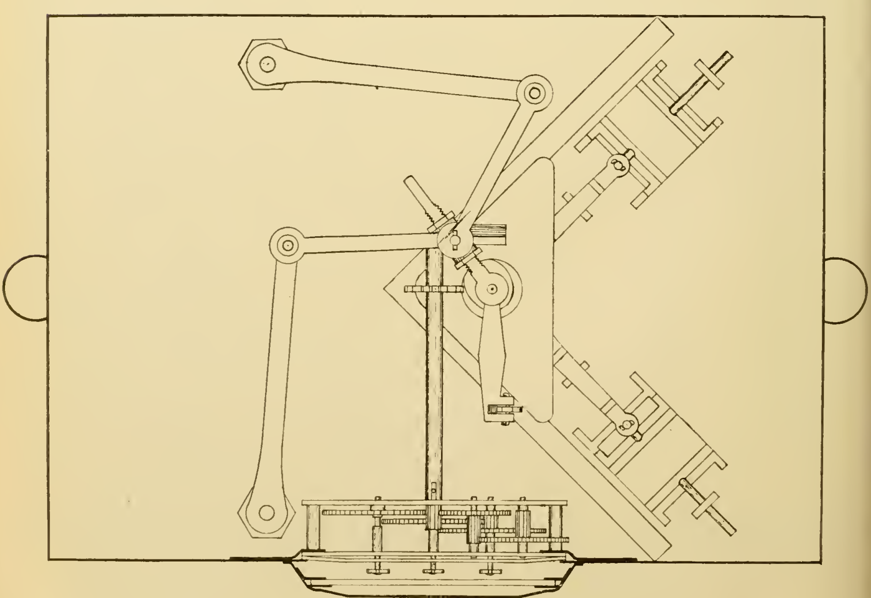


Dry Meter, Showing Diaphragms and Leathers.



Vertical Section through Centres of Flag & Crank Shafts.

DRY METER.



Plan View of Works.

DRY METER.

or drum is divided by partitions into buckets or chambers in such a way as to admit the gas into one of the partitions above the water. The pressure of the gas acting against the partition on one side and the water on the other causes it to revolve, and just before this section begins to shut off from the supply another section comes in and begins to take gas. Immediately after this, the first section shuts off the intake, and, being already filled with gas, begins to discharge the gas into the case which surrounds the drum. Given the exact cubical contents of these various chambers, the quantity of gas passed with one revolution of the drum can be ascertained, and properly constructed gear wheels, operated by a pinion on the main shaft, register the amount of gas that passes.

The dry meter operates through two side valves, and the working parts of the meter are two or more diaphragms attached to the valves by means of rocking shafts and link motion. The diaphragms are given freedom of movement by means of leathers attached to the diaphragms and to the partition between them, and the whole is inclosed in a case. As gas is admitted on both sides of the diaphragms, it is evident that movement of either diaphragm causes a flow of gas to the outlet of the meter. When one diaphragm is on the dead center, the other one is in full action, thereby producing a steady flow of gas. The links operate a crank shaft, and this crank shaft operates the valves and the registering gear. The area of the moving diaphragm, multiplied by its lineal travel, will give the cubical displacement, and the consequent flow of gas can be known for a given number of movements of the diaphragms. The diaphragm leathers are soaked in oil, and so long as they remain sound the registration of the meter will continue correct. The chief difficulty, however, is that these leathers in time become hard, and the constant movement of the diaphragm cracks them and a portion of the gas begins to pass through without registering.

Fully 90 per cent. of the dry meters that are wrong are found to be slow. One can readily see from the construction of the meter that in order to make the meter run fast the travel of the diaphragm must be reduced, but the limitations of the crank shaft require a certain amount of motion on the part of the diaphragm to pass the dead center, and if this is not met, the meter will refuse to operate.

BURNERS.

The original cock spur gas jet burning a 14 C. P. gas produced about 2 candles of light per cubic foot of gas consumed per hour, or on 5 feet per hour, which is the standard consumption per

hour and basis of all reference to candle power of gas, would produce 10 candles of light. As improvements were made the quality of gas was raised, and 18 candle gas with an ordinary gas jet produces from $3\frac{1}{2}$ to 4 candles per foot of gas consumed per hour. The common Argand burner produces less than this. The Sugg Standard English Argand produces 4 to $4\frac{1}{4}$ candles per foot, and the Siemens and Lungren lamps increase this yield of light to about 10 candles of light per cubic foot of gas consumed per hour. The Welsbach light, when first put on the market, gave a fraction over 12 candles of light per foot of gas consumed per hour, while the Welsbach single burner of to-day gives something over 20 candles of light per cubic foot of gas consumed, and the inclosed incandescent gas lamp, known as the "gas arc," will give as high as 25 and sometimes 30 candles of light per cubic foot of gas consumed per hour.

NEW ORLEANS.

In 1829, on the 7th day of February, the Legislature of the State of Louisiana passed an act incorporating a company under the title of the New Orleans Gas Light Company. This franchise was declared forfeited in 1833, and the exclusive privilege of vending gas lights in the city was given to James H. Caldwell, of New Orleans. In 1835, by an act of the Legislature, Mr. Caldwell transferred his privileges to the New Orleans Gas Light and Banking Company. The banking rights of the company were later relinquished. In 1881 an opposition company was projected, and, as a result of four years' litigation, the Supreme Court of the United States, in 1885, confirmed the exclusive rights of the present company, as granted by its charter, to make and vend gas lights until April 1, 1925.

One of the provisions of the grant was that the price of gas should never be raised above $6 per 1000 cubic feet. In 1854 there was another amendment to the charter, which provided that the price of gas should not be above $4.50 per 1000 cubic feet.

The first plant was erected in 1836, and consisted of three benches, of three iron retorts each, on the corner of Gravier and Locust Streets (now known as Robertson Street). The plant was enlarged about 1850 or 1852 to sixteen benches of three iron retorts each.

In 1859 the building that is now used as a generator room was erected, and in it were installed forty benches of three clay retorts each, each retort being 12 x 20 inches and 8 feet 16 inches long. The hydraulic main was circular in section, 18 inches in diameter, and the benches were supplied with 4-inch stand pipes. About 1868

there were placed in these benches five retorts, space for them being created by lowering the floor line of the retort house and setting the furnace lower down. The same hydraulic mains were adapted to this change.

These benches were used until the consumption had reached 1,100,000 cubic feet per day, and about 1875, the retort house, on the corner of Perdido and Magnolia Streets, was built, and in it was installed forty-eight benches of six retorts each. These benches made all the gas until about 1883, when the Egerton process for making gas was put in.

This process consists of a set of generators for producing water gas and an evaporator for vaporizing naphtha. The naphtha vapor was taken up by the water gas and carried along through heated retorts as fixing chambers. This was the time the "dollar-and-cent meter" was put into use in New Orleans, and 33 candle gas was made. Many of these dollar-and-cent meters are still in use in the city. The rate on these meters is $3.70 per 1000, and, in order to reduce the registration of the dollar-and-cent meter to cubic feet, it should be divided by 3.7. This, or a similar water-gas process, was used until 1895, when a standard Lowe water-gas plant was installed and has since been in continuous operation.

I have already referred to the mechanical accountant—the station meter. All of the gas made is measured by this station meter, and, at the close of a month's business, all gas registered by the consumers' meters is totaled up, and the difference between the amount made and the amount sold is ascertained. This amount will vary in different plants, and is largely dependent upon a variety of conditions, viz: the temperature at which the gas is measured in the station meter, the tightness of the mains and the correctness of the consumers' meters.

To overcome the question of temperature the quantity of gas measured by the meter is corrected to a uniform temperature, say 60 or 70 degrees, according to the climate in which the business is being conducted. Notwithstanding this fact, it is never found, at the end of the year, that all of the gas sent out into the mains has been sold, and, if the loss is no greater than 8 per cent., it is concluded that mains and meters are in excellent condition; but cases are on record where the loss has been as great as 25 per cent., and even a few instances where it has reached 50 per cent., in the early days when wooden mains were considered the very thing.

In New Orleans the question of leakage has not been very serious, because of the presence of water in the ground at practi-

cally all times of the year. We have little trouble over the loss of gas from its getting out of the mains, because where there is a leak in the main there is water enough present in the ground, with sufficient pressure to prevent the gas from leaking out; instead, the water leaks in, and, as a result, we have a large expense account for pumping water out of the mains. If the ground became well drained and the usual conditions of elevated land existed, no doubt our leakage account would be as large as other well-regulated plants. This seepage of water into the mains gradually causes the formation of a deposit, which finally has to be removed. This process of washing out the gas mains is, I believe, peculiar to New Orleans. The mains are flushed in this manner: The main and branches of two or three blocks are cut and plugged, and a hose is attached from a fire hydrant to the main; the main is filled with water under pressure, and the plug at the far end is knocked out and the water allowed to gush through, after which it is washed for eighteen or twenty minutes, and thereby the mass of sediment at the bottom of the mains is removed. This accumulation has become so great in some instances that it has retarded the flow of gas during the early hours of the evenings to such an extent that certain sections have been entirely without gas.

In the distribution of gas from the holders, all of the pressure of gas in the mains is given by the weight of the holder. In order to maintain uniform pressure and not to have a presssure on the mains higher than is necessary to give a good service, governors of the pressure are used at the works. These are operated in a manner to produce a pressure according to the demand on the mains, but in the rapid development of the gas business recently experienced in New Orleans, the demand on the mains was far greater than the supply of gas that could be forced through them with the weight of the holders, and even had they been heavy enough, it would have been undesirable, because the pressure would have been excessive to the extreme in the pipes leading out from the works, and would have gradually diminished until out or near the extreme limits of the system, and the proper pressure would not be obtained. In order to overcome this difficulty promptly, and at a reasonable cost, a high-pressure system of distribution was introduced in New Orleans, and has been in operation for about a year past. This system consists in compressing the gas to from 15 to 35 pounds, and sending it out to the outlying districts in small wrought-iron mains, laid expressly for the purpose, to a desired point where the gas is fed into the low-pressure mains and the pressure is re-

duced through a regulator to the proper amount to be maintained in the low-pressure mains. At the present time there are four such stations in the city. The entire gas supply of Algiers is furnished through a high-pressure pipe, which is laid on the bed of the Mississippi River, and the low-pressure distribution pipes in Algiers are

CURVE SHOWING HOURLY OUTPUT FOR ONE DAY EACH IN OCTOBER AND AUGUST.

supplied with gas through a small governor station on the Algiers side of the river. So far, this method of distribution of gas has proved eminently satisfactory, and the gas supply of Algiers has been interrupted on but two occasions in the six months since it was turned on. This was necessitated by the breaking of a fitting in the high-pressure piping at the governor station in Algiers, and the change of fittings was accomplished in less than an hour. The

other shut-off was occasioned by the necessity of lowering the main on this side of the river at the head of Julia Street, and, in order to keep the supply of gas on while this lowering process was going on, a heavy 2-inch steam hose was inserted in the pipe in order to give a flexible connection to permit the pipe to descend, keeping the gas on all the time. This 2-inch rubber hose is still doing business in the turbid flood that has been rushing by for several weeks past, but no interruption of the supply has occurred.

The old Valence Street Works, formerly the Jefferson City Works, have long since been abandoned for manufacturing, and only the storage holders at this plant are in use. These holders are filled daily from the high-pressure main which was carried there for that purpose.

The hourly consumption of gas is subject to quite a large variation during the twenty-four hours, and there is a distinct peak of load as in the electric consumption for electric light. The accompanying diagram shows this peak.

The history of the gas business in New Orleans is almost the history of the gas business in the United States. It was the second gas works built in this country. To-day the gas of New Orleans is made with the most modern apparatus known, and if it is safe to predict from the past, New Orleans will be one of the first to avail itself of any material improvements which may be made in the manufacture of gas.

GOOD ROADS.

By George C. Diehl, Member Engineers' Society of Western New York.

[Read before the Society, April 7, 1903.*]

Mr. President and Gentlemen:—The public press has wisely published very complete reports of the various good-roads speeches, meetings, conventions and legislative enactments; and doubtless I can but repeat facts familiar to you.

It is the duty of every member of this Society, when called upon by the Secretary, to address the members on the subjects with which he is familiar, from his experience as an engineer; and from that standpoint I will state some ideas concerning good roads which have come to my notice in an official capacity, while employed by the State Engineer's Department and by the Board of Supervisors as County Engineer. I must confess I had never given much thought to good roads or bad roads before I was paid for doing so.

This was a mistake, and I believe it the duty of every patriotic citizen to inform himself and lend his aid to every worthy improvement of the commonwealth and the municipality. Especially is this true of every engineer, on such great subjects of the State's internal improvement as the construction of a 1000-ton barge canal and the improvement of the public highways; for these public problems could be more quickly solved and the apparently insurmountable obstacles overcome should the engineers of the State devote some of their time, energy and ability to this patriotic duty.

It is only since the early nineties that the improvement of the public highways has been systematically carried on and public opinion sufficiently aroused to the necessity of action by our various legislative bodies.

A history of the good-roads movement, previous to the nineties, would chronicle the persistent efforts of a few pioneers, meeting with little encouragement, working without system, but steadfastly sticking to their task and making possible this great internal improvement by enlightening the public mind to the necessities for the betterment of transportation facilities to the great avenues of commerce—the railroads and the waterways.

Four methods of improvement of highways suggest themselves to me: (1) with National aid; (2) with State aid; (3) by the county; (4) by the town or locality.

For a number of years the National Department of Agriculture

*Manuscript received November 11, 1903.—Secretary, Ass'n of Eng. Socs.

has had a Good-Roads Department, which has made valuable studies in geology, petrology, character of soils and various natural conditions, has built short experimental sections of road illustrative of the various types of roadways, and more recently this Department has operated the so-called "good-roads trains," equipped with modern stone crushers, rollers, road machines, etc. These trains have been sent through the Southern and Western States, where the good-roads movements are not so far advanced, and have stopped about a week in each locality and built a section of sample road, inviting everyone and educating them along the most improved lines of road building.

A bill has recently been introduced into the National Congress by W. P. Brownlow, which provides for a system of National, State and local co-operation in the permanent improvement of the public highways. This bill contemplates an appropriation of $20,000,000, which shall be apportioned amongst the various States in proportion to their populations, the Government to pay one-half and the State and locality one-half of total cost of road. It is also provided that a bureau shall be created under the direction and management of the Secretary of Agriculture, consisting of a director, at $4500 per annum; four field experts, at $2000 per annum; four civil engineers, at $1800 per annum; four road experts, at $1400 per annum, and others. The remaining features of the bill are similar to the Higby-Armstrong Bill of this State, of which mention will be made later.

In the improvement of highways with State aid, I believe the States of Massachusetts and New Jersey were the pioneers. The system adopted by the former State is regarded by many to be drawn along the most advanced lines. The States of Connecticut, Maryland and others have added greatly to the public store of knowledge. The work in Massachusetts, both in construction and maintenance, is done under the direction of a commission of three, appointed by the Governor, for a term of five years, terms expiring separately, so that always two experienced members remain on commission. However, time will not permit me to go into detail of work done in other States.

On March 24, 1898, the so-called Higby-Armstrong Good-Roads Bill became a law in New York State. This law, in a general way, provides that the owners of a majority of lineal feet fronting on any public highway may present to the Board of Supervisors a petition, setting forth that they desire such highway improved under the provisions of this act. The Board of Supervisors must pass a

resolution (or, if no petition has been circulated, may pass a resolution) that the public interest demands said improvement. A certified copy of this resolution is sent to the State Engineer, who investigates and determines if the section of road is of sufficient public importance to come within the provisions of this act, taking into account the use, location and value of such highway for the purposes of common traffic and travel. Should the State Engineer approve of such resolution, he shall cause the road to be surveyed and mapped and plans and estimates of cost of improvements made; the macadam portion of the road to be 8 to 16 feet in width, unless for special reasons given by the State Engineer it is required to be of greater width. He shall then submit to the Board of Supervisors estimate and certified copy of plans. The Board of Supervisors may, by a majority vote, adopt a resolution that such road be improved. The State Engineer then advertises for bids for said improvement and awards the contract, which must be at a price less than his estimate, but may, in his discretion, be awarded to the Board of Supervisors, even though not the lowest bidder. Fifty per cent. of the expense of construction shall be paid by the State and 50 per cent. by the county in the first instance; of which latter 50 per cent. 35 per cent. of the total cost of construction shall be a general county charge, and 15 per cent. shall be charged to the town in which the road is built, if without petition; or to the abutting property owners, if built by their petition.

The improvement of such highways shall be taken up in the order in which the State Engineer shall receive the resolutions of the Board of Supervisors, which approve of the plans and estimate. The property owners shall thereafter pay all highway taxes assessed against them in money. The bill also provides for collecting statistics, consultation by highway officers, annual report to Legislature, that the road shall be maintained thereafter as a county road, and that the Commissioner of Highways shall care for same as directed by the State Engineer.

The appropriations which have been made by the State and counties under this law are as follows:

	State.	Counties.
1898	$50,000	$63,872
1899	50,000	42,876
1900	150,000	431,227
1901	420,000	1,055,874
1902	795,000	1,748,115
	$1,465,000	$3,341,964

Forty-six different counties have petitioned for State aid, and the totals for the State are as follows:

Mileage petitioned for to January 1, 1903	2415
Mileage plans approved by counties	825
Mileage completed	186
Mileage in process of improvement	167

In Erie County—

The total mileage of roads outside of Buffalo and incorporated villages is	1900
Mileage petitioned for to January 1, 1903	77
Mileage plans approved by county to January 1, 1903	53
Mileage completed	12
Mileage in process of improvement	20

This law is applicable only to the main market roads in the State. The total mileage of roads in New York State, exclusive of cities and incorporated villages, is approximately 73,800. Approximately 10 per cent. of this mileage can be improved under this law, or about 7500 miles, at $8000 per mile, a total cost of about $60,000,000. If the State should appropriate $1,000,000 a year, this improvement would take at least thirty years, and it is for that reason that the good-roads advocates are urging the Legislature to approve of a $50,000,000 bond issue for the improvement of roads that the commonwealth might derive the benefit of these improved highways at an early date, and that produce might also be brought to main shipping centers from points now well-nigh inaccessible.

The total acreage of farms in New York State, according to the United States Census, was: 21,961,562 acres in 1890 and 22,648,109 acres in 1900, an increase of 686,547 acres.

The value of farm lands, fences and buildings was: $968,127,286 in 1890 and $888,134,190 in 1900, a decrease of $79,993,096 in ten years.

In 1890 New York State ranked third in agriculture.

In 1900 New York State ranked fourth in agriculture.

The advocates of a large bond issue for good roads contend, and I think rightly, that improved highways will increase farm values just as trolley lines have created values in cities and suburban localities, and that improved transportation facilities are an absolute necessity, if the commercial supremacy is to be maintained.

The General Highway Law also provides that for the county road system, under the provisions of this enactment, the Board of Supervisors may, by a majority vote, designate the leading market roads lying outside of the limits of a city, and cause such designation

and a map of such roads to be filed in the County Clerk's office. Such roads may then be improved, repaired and maintained as a county charge, under the direction of the Board of Supervisors and a County Engineer.

As before stated, the Higby-Armstrong Law applies to only about 7500 miles. There remain approximately 66,300 miles of road which must be improved under some other system.

To appreciate this vast mileage of roads to be improved, I cite from the New Jersey Good-Roads Report for 1902:

The Total Miles of Pavement of all Kinds in the United States.

Cobblestone	1,000
Granite and Belgian block	3,500
Brick	2,000
Wooden block	1,500
Asphalt	3,500
Gravel	4,500
Macadam	4,000
Total	20,000

There is now on the statute books an enactment known as "The Fuller Law," which, in a general way, provides that any town may adopt a cash system of collecting highway taxes, and thereafter for each dollar collected the State will pay to such town 50 cents; not, however, to exceed one-tenth of 1 per cent. of the assessed valuation of said town. It is also provided that the town must make the present labor tax payable in money in a minimum of at least 50 cents on a dollar of the present commutation rates.

The total assessed valuation in the State, exclusive of incorporated cities and villages, is approximately $360,000,000. Thus the annual payment by the State would not exceed about $360,000. The present method of road improvement (in the majority of towns) is by day-labor, under the direction of highway commissioners, who appoint overseers in the various highway districts. This antiquated system of road improvement is a relic of the ancient English law, which became our law after the Revolutionary War.

There are about 1000 highway commissioners, 50,000 overseers and an annual expenditure of $2,000,000 day-labor. Each mile has a different overseer and a different system, and much unnecessary work, and more well-intended but absolutely useless work, is done. At $1.50 for each day's labor there is spent $3,000,000 per annum, so that in twenty years approximately $60,000,000 has been spent. How little there is to show for this vast expenditure, anyone who drives in the country can tell.

Should the entire State adopt the Fuller system the 1000 high-

way commissioners would have at least $1,500,000 annually to spend on the roads. Many of these highway commissioners know little of road improvement, having had no experience, although well meaning, and under competent superintendence probably would be efficient. And it is provided by Act, Chapter 396, of the Laws of 1902, that each county may appoint a County Engineer, who may be consulted by the highway commissioners and who may establish grades, indicate methods of drainage and improvement, etc., and, in short, superintend and direct all the work done by the highway commissioners.

The benefits derived under the Fuller Law up to January 1, 1903, are as follows:

	No. of Counties Benefited.	No. of Towns Benefited.	Amount of State Aid.
1898	8	43	$34,517
1899	14	75	54,057
1900	21	100	67,655
1901	24	139	102,509
1902	40	258	246,000 (approx.)

The question of wide tires, which I will but briefly mention, is one most vital to the maintenance of improved highways. In this country the narrow tire is in general use, although many tests have been made fully demonstrating the claims in favor of wide tires, less draft required, maintenance of roads in better condition, etc.

I have recommended to the Board of Supervisors, at various times, the adoption of a "wide-tire" law, but none has yet been adopted. In Europe narrow tires have long since been discarded, and every wagon is a road maker. Tires vary from 3 to 10 inches in width, and rear axles are longer than fore axles, so that wheels do not run in same track. The width of tires is determined in various ways, usually differing in various localities; but all achieve practically the same result. Some localities allow 550 pounds per inch width of tire.

The resolutions introduced in the Erie County Board of Supervisors provide that all wagons built to carry 1500 pounds or more, equipped with thimble-skein axle of 3 inches diameter or less, or steel axles of $1\frac{5}{8}$ inches diameter or less, or tubular axles of $2\frac{3}{8}$ inches diameter or less shall have a tire not less than 3 inches in width. With the corresponding types of axles, $3\frac{1}{4}$ inches, $1\frac{3}{4}$ inches, $2\frac{5}{8}$ inches in diameter, respectively, they shall have a tire not less than $3\frac{1}{2}$ inches in width. With corresponding axles, $3\frac{1}{2}$ inches, $1\frac{7}{8}$ inches, $2\frac{7}{8}$ inches or more, respectively, they shall have tires not less than 4 inches in width. The resolution made other provisions.

Briefly, the work that has been done with State aid, under the Higby-Armstrong Law in Erie County, is as follows:

The first road improved in this county was the Whites Corners Road, extending from the southerly city line, southerly to the village of Hamburg; built, 1898, 1899, 1900; length, 6.54 miles; total cost, $30,928; width of macadam, 12 feet; thickness, 6 inches; material, local limestone. The subsoil is a clay, with some quicksand. The road was more or less a failure, and a second contract was made to resurface the road with 2 inches of trap-rock, and widen to 20 feet that portion from city line to Limestone Hill (about ½ mile) and to place drain tile in soft spots. The total cost of second contract was $24,294. Present condition: south end, good; north end, poor; due, in my judgment, to macadam being too thin.

The next roads built were:

The River Road. Extends from the northerly city line at Niagara Street, northerly; built, 1900; length, 1.46 miles. Total cost, $17,000; width of macadam, 20 feet; thickness, 6 inches of macadam, 4 inches of gravel. Material, top 2 inches trap-rock, remainder local stone; condition, good.

The Orchard Park Road, Section No. 1. Extends from village of Orchard Park, northwesterly toward Buffalo; built, 1900. Length, 1.12 miles; width of macadam, 16 feet; thickness, 6 inches; material, top 2 inches trap-rock, remainder local stone. Condition, good. Total cost, $14,619.

Main Street Road, Section No. 1. Extends northeasterly from Main Street city line. Built, 1902. Length, 3.42 miles. Contract price, $25,000; width of macadam, 16 feet; thickness, 6 inches. Material, local limestone from Almshouse quarry. Condition, good.

There are now in process of construction the following roads:

Main Street, Section No. 2. Extends easterly from Williamsville to Transit Road. Length, 1.93 miles. Contract price, $15,100.

Transit Road, Section No. 1. Extends northerly from Main Street Road. Length, 4.28 miles. Contract price, $35,400.

Transit Road, Section No. 2. Extends northerly from Transit Road, Section No. 1, to north line of Erie County. Length, 4.06 miles. Contract price, $37,700.

Orchard Park Road, Sections 2, 3 and 4. Extends from Orchard Park Road, Section No. 1, to the Seneca Street city line. Length, 5.53 miles. Contract price, $79,300.

Big Tree Road. Extends from East Aurora easterly to Wales Center. Length, 4.00 miles. Contract price, $38,637.

There will probably be built this year:

Main Street Road, Sections 3 and 4. Extends from Main Street Road, Section 2, to easterly county line. Length, 12.20 miles. Estimated cost, $77,900.

River Road, Sections 2 and 3. Extends from River Road, Section No. 1, to village of Tonawanda. Length, 3.02 miles. Estimated cost, $26,400.

Aurora-Buffalo Road, Section No. 1. Extends from Seneca Street city line to town of Elma. Length, 5.57 miles. Estimated cost, $56,000.

I must apologize to you for discussing this subject more from the viewpoint of a layman than of an engineer, but unfortunately I had not sufficient time since my notification by the Secretary to prepare a paper along engineering lines. I would be pleased, however, to answer any questions that I can, and at some subsequent meeting, when a paper is wanted to fill in, I would gladly give what few ideas have come to me in my limited experience about surveys, plans, drainage, various road metals, character and treatment of subsoils, maintenance, stone-crushing plants and others.

CONCRETE-METAL CONSTRUCTION.

By Emile Villet, C.E., Member Technical Society of the Pacific Coast.

[Read before the Society, March 6, 1903.*]

In the hope that I may have the pleasure of imparting some new feature in the art of armored cement construction, as executed in foreign lands, I present these few pages, which refer to work performed, existing, and resisting the elements, and to work projected and under actual study; to wit:

(1) The wharf constructed at the port of Novorossisk, in Russia, on the Black Sea.

(2) The plan of wharf and wharf superstructure, entirely of cement and iron, drawn for the Department of Docks of New York city.

(3) A proposed plan of sea-wall construction, also entirely of cement and iron, made for the Board of Harbor Commissioners of San Francisco.

DESCRIPTION OF THE ARMORED CONCRETE WHARF AT NOVOROSSISK.

In 1896, Novorossisk having become an oil shipping point on the Black Sea, by reason of its geographical position with regard to the recently opened Trans-Caspian Railroad, now running through the oil regions of Southern Russia, a wharf of the ordinary wood-pile system was constructed to accommodate the steamships of 4000 to 5000 tons, about to engage in the petroleum carrying trade. This structure, attacked to some extent by the teredo, was partially destroyed by the fouling of a steamship and by the force of the rough seas which prevail during stormy weather in the Black Sea.

After the accident I was called to Novorossisk from the city of Kertch, where, during four years prior, I had constructed the sewer system, reservoirs, bridges, coal bunkers, etc., all of armored concrete, in order to reconstruct, in armored concrete, for the account of the owners, the portion of the wharf which had been destroyed.

The destroyed portion was built in two parts:

(1) The wharf proper, 70 feet long and 52 feet 6 inches wide.

(2) A footbridge, 37 feet 6 inches long and 19 feet 6 inches wide, connecting the remaining pile wharf to the new portion above mentioned.

These two portions give a floor area of 3724 square feet.

*Manuscript received September 8, 1903.—Secretary, Ass'n of Eng. Socs.

The floor, constructed of armored concrete 4 inches in thickness, is supported by twenty-four piles, $15\frac{3}{4}$ x $15\frac{3}{4}$ inches, joined together by stringers, $15\frac{3}{4}$ x $25\frac{3}{8}$ inches, forming spans 16 feet $4\frac{3}{4}$ inches from axis to axis. In each span these stringers are joined by five small beams, $7\frac{7}{8}$ x $11\frac{13}{16}$ inches.

By the terms of the contract, the structure must bear a test of a permanent weight of 213 pounds per square foot. The following is a copy of the test certificate, with accompanying diagram:

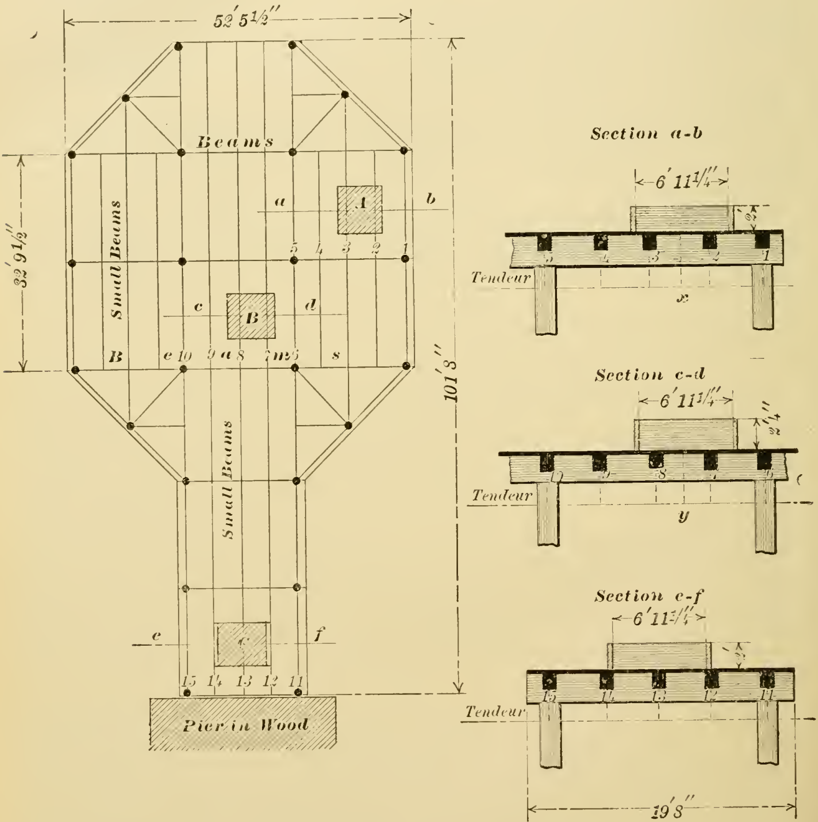


Fig. 1. Plan of Pier at Novorossisk, Russia.

"Certificates as to the tests made of the part of the wharf built on piles with stringers, small beams and flooring, all of reinforced concrete, in accordance with the Russian Standard, at Novorossisk, Russia.

"On the 27th and 28th of May, in the presence of Mr. Maklarene, engine builder, and Mr. Freichist, engineer for bridges and roads, both residing at Novorossisk, resistance tests were made of the

wharf built of reinforced concrete by Mr. Emile Villet, C. E., and contractor of Novorossisk.

"According to the conditions prescribed by the contract of the 5th of June, 1900, the flooring must be capable of supporting a load of 213 English pounds per square foot.

"In order to make the tests bear on some weak points of the flooring, the points indicated by the letters A, B and C have been designated.

"The bays, submitted to the tests, rest on piles $15\frac{5}{8}$ x $15\frac{5}{8}$ inches, spaced 16 feet $4\frac{3}{4}$ inches from axis to axis; at each point the load affected a surface of 41 feet $5\frac{7}{16}$ inches.

"In order to measure the deflections, hangers were placed below the floor, and the distances from the hangers to the small beams (numbered from one to fifteen) and from the points z and y were taken and exactly noted.

"On the 27th of May, at 10 o'clock A.M., the boxes A and C were filled with gravel up to a height of 2 feet. Box B was filled with sand up to a height of 2 feet 4 inches. The given dimensions multiplied by the specific weight of the gravel and sand gave exactly a load of 213 English pounds per square foot.

"After the termination of the test, the flooring showed no deflection; twenty-four hours later, that is to say on the 28th of May, the flooring showed no deflection.

"Novorossisk, May 29, 1902. MAKLARENE,
"(Signed) FREICHIST."

The piles are square, $15\frac{3}{4}$ x $15\frac{3}{4}$ inches and 42 feet long, giving a cubic measurement of 2.7 cubic yards, which, at the density of 2.5 for the armored concrete, gives a total weight of 11,025 pounds, or 262 pounds per linear foot.

Each pile, having to support a floor surface of 269 square feet, should resist satisfactorily a compression of 85,584 pounds thus distributed:

Live weight, 269 square feet x 213 pounds	57,297	pounds.
Dead weight, floor, 269 x 52 feet	13,624	"
Stringers	6,615	"
Small beams	8,048	"
	85,584	"
to which add		
Coefficient of security 50 per cent. on live load of 57,297	28,649	"
Total	114,233	"

It is to be noted that the compressive strength is asked only of the iron composing the frame of the pile, and that the resistance

offered by the cement is not taken into account, the latter being considered as fulfilling simply the rôle of protector of the iron against the action of the salt water of the sea.

The iron frame of the pile is composed of eight bars of round iron, which are bound together every 10 inches by bands and by

Fig. 4

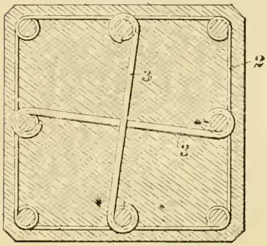


Fig. 7

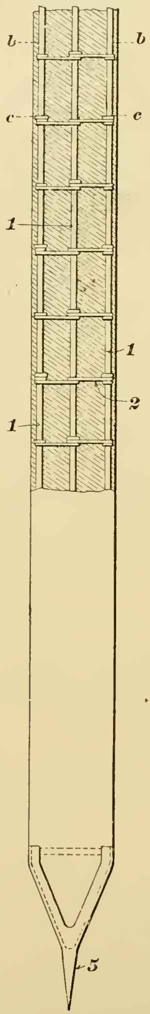


Fig. 2

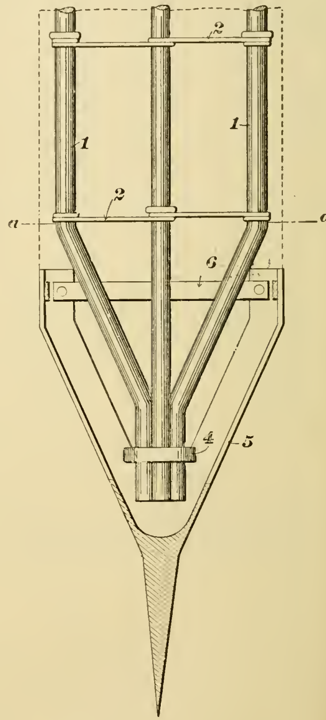


Fig. 5

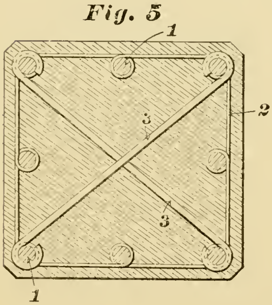


Fig. 6

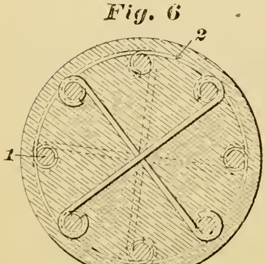
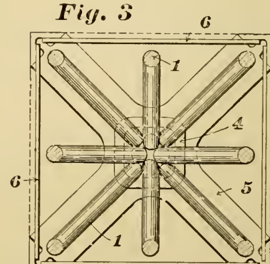


Fig. 3



ties, the latter diagonally joining the corner bars or the middle bars alternately, as shown in Figs. 4 and 5, on drawings accompanying patent.

The object of these ties, placed in the center of the body of the concrete, is to prevent the splitting of the central part under

the action of the pile-driving hammer. The quantity of iron for each linear foot of pile is 45 pounds.

Regarding the composition of the concrete for the construction of piles, gravel cannot be used because of its imperfect union with the cement to withstand the effect of the blows of the pile driver; only siliceous or quartzose sand, perfectly cleaned, can be used, and the cement, united with it and properly rammed, forms, with the sand, a homogeneous and solid monolith.

For a pile 42 feet long there are used: Sand, 2400 cubic yards. Cement, 3800 pounds. Water, quantity to be determined according to the quality of cement to be employed. In all other parts mixtures are made with quartz gravel, sand and cement.

Russian cement was used at Novorossisk, sand as above and the sea water of the Black Sea for mixing purposes.

The piles are constructed horizontally, and, after the removal of the mold in which they were formed, they are exposed to the atmosphere for several days, at the expiration of which they are immersed in water, where the process of solidification is completed. The duration of the immersion depends upon the nature of the cement used.

Thus any desired number of piles may be constructed at or near the projected wharf before the work of construction is commenced.

Fig. 2 shows the mode of construction of the iron frame at its penetrating part. (See drawings on patent.)

The pile driving is accomplished in the ordinary manner. After dropping the pile into position from a height of about 14 feet, which drop has shown a penetration of an average of 1 foot 6 inches into the hard calcareous bottom of the harbor of Novorossisk, the hammer, weighing 3375 pounds, is dropped from a height of 12 to 14 feet upon the head of the pile, striking an average of twelve blows and until the penetration has reached, on an average, 2 feet.

The piles are constructed of a length greater by 6 feet than the depth of the soundings actually shown, so as to admit of cutting the heads of the piles to a uniform level, and removing such portion of the piles, close to the head, which becomes splintered by the action of the hammer, notwithstanding the use of a cushion of wood placed on the head of the pile.

In leveling the heads of the piles the cement work only is removed and the protruding bars of the iron frame are then bent over and become locked with the armored concrete stringer, which

is constructed from pile to pile and forms, with the stringers, a homogeneous mass, thus preventing all shearing and torsion.

The beams and braces are made of prisms of a rectangular or square section; and the iron frames, forming ties or tie rods, are placed in their interior.

These frames and the body of the cement are calculated to resist deflection (compression), rupture (tension) and shear.

These beams and braces may be constructed in long spans.

In the construction of wharves, the rôle of the braces is to localize, at a certain point in the height of the piles, the lateral effects to which the wharves are subjected by the fouling of vessels,

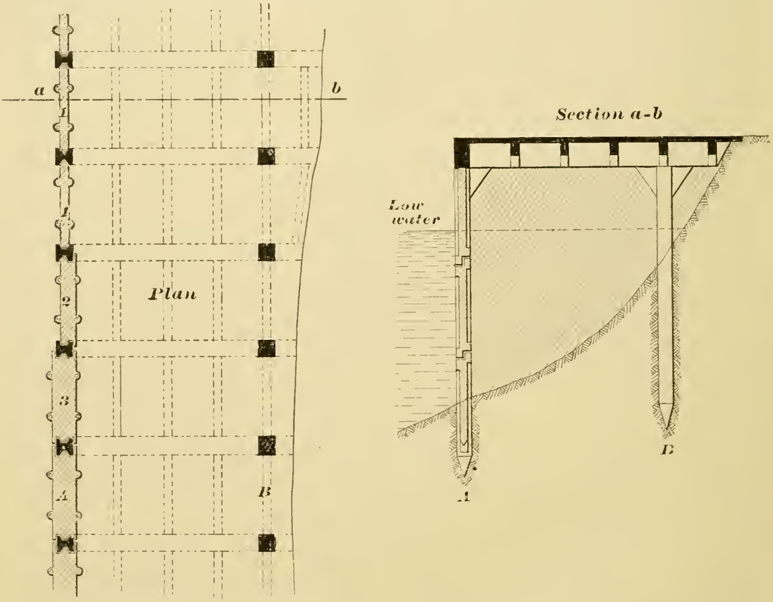


Fig. 8. Project of Wall with Piles and Panels of Cement Armé.

sometimes quite violently, and to distribute the effects over all that part of the structure which emerges above the level of the sea.

These braces are made on the spot and united with the piles without any articulation; that is to say, they are cemented into the piles.

At Novorossisk they were constructed in one horizontal plane, at 4 inches above low water, and their dimensions were $11\frac{13}{16}$ x $7\frac{7}{8}$ inches. The construction, a single horizontal plane, obviates the possibility of shearing action, caused by lateral efforts, to which the structure would be subjected if the braces were placed at different levels.

The many uses to which armored concrete may be put require

no special form of iron, and any iron, round, square or flat, can be employed.

In the construction of all kinds of armored concrete, even in the making of columns, floorings and walls of buildings, the various parts are molded and constructed on the spot, without the need of heavy and costly hoisting machinery.

With regard to the labor, I would say that experienced or inexperienced men are trained to do the work. In Russia, where competent cement workers could not be obtained, I trained men accustomed to do only ordinary laborer's work, who, in a short time, became efficient in the art.

Observations.—The advantages offered by concrete piles, as compared with wooden piles, are the following:

(1) The contact of the water hardens them more and more.
(2) Their life is unlimited, and they require no repairs.
(3) They are fireproof.
(4) They can be used as columns to support heavy loads.

PLAN OF ARMORED WHARF CONSTRUCTION FOR NEW YORK.

In July, 1902, during my sojourn in New York, at the request of the Department of Wharves and Docks, I made plans for a wharf and its shed, to be entirely constructed of armored concrete.

In this port the great difficulty arises from the great depth of the solid bottom, which, in some parts, is 160 feet, such depth having been given as the maximum.

The plan which I submitted provides for piles 160 feet long, which would be constructed in three pieces and cemented together end to end, the pile in a vertical position.

By reason of the slowness of this method of construction for long piles, and of their cost, which absorbs nearly three-fourths of the cost of the wharf, the Department of Docks asked me, in September, 1902, whether it would be possible to make the piles shorter by taking into account the effort of friction of the mud upon the wooden piles.

In order to scientifically determine the possibility of employing armored concrete piles 83 feet long (the length of the wooden piles), it was necessary (1) to establish the surface of friction of the wooden pile, imbedded 49 feet in the mud, which had been increased by blocks of wood bolted to the pile, hence: Surface of friction of the pile, 110 square feet; surface of friction of applied blocks, 99 square feet; total, 209 square feet. (2) To take into acount the difference of density between armored concrete and wood, a differ-

ence which caused me to reduce the weight of the armored concrete pile.

In consequence my studies bore on a pile, 83 feet long 20 x 20 inches, hollow in the center throughout its entire length, which would give for each linear foot a surface of friction of 6.96 square feet, and, for a depth of 49 feet, 49 x 6.96 = 329.64 square feet, or over and above the wood pile; 329.64 — 209 = 120.64 square feet. This surface might be increased by the surface of friction given by the interior cylinder 8 inches in diameter, but I prefer to neglect this surface of friction.

A hollow pile of the aforesaid length can be constructed, thus eliminating all connections and forming no disturbing element in the usual run of the work. Its cost price is not to be compared with that of the first project.

CITY OF SAN FRANCISCO.

After a careful study of the combined pile—wood and cement —invented by Howard Holmes and Carl Uhlig, of the San Francisco Harbor Commission, I resolved to apply the same idea to the construction of a hollow reinforced concrete pile. I studied the two applications of hollow piles made actually in the harbor of San Francisco. The first consists of a combined pile, having in its center three wooden piles (Wharf No. 10 at the foot of Howard Street), the second being a combined pile with only one wooden pile in the center (Wharf No. 9 being built at the foot of Broadway Street). The work on Wharf No. 9 is being performed by the Hyde Construction Co., to whom I am indebted for information on this subject.

This information, based upon actual tests, showed that the weight of the reinforced concrete pile is almost the same as that of the combined pile, about 22,000 pounds, and, although the former was loaded with fifty tons and the latter with thirty-eight tons, it was subjected to a surface friction of 4.813 pounds per square inch, while the combined wooden pile resulted in 5.877 pounds per square inch of imbedded surface; that is, of it was required twenty-two per cent. more frictional resistance than of the reinforced pile provided in the Villet construction.

Up to a length of 50 feet the pile can be considered as a standard pile, the building of which is an easy matter. If necessary, these piles could be made 83 feet long and over, in which case the outside of friction would be correspondingly increased.

Taking it for granted that experience will show that the Holmes pile will really last twenty-five years, as predicted, the life of such

piles would still be comparatively short when we take in consideration the high cost of placing them. Moreover, such piles are not adapted for any kind of floor but a wooden one.

There is practically no limit to the life of a reinforced concrete pile, and besides they present the great advantage of allowing a reinforced concrete floor to be substituted for the wooden one whenever desired. In view of the possibility of such a floor being required in the future, they can be constructed with two consols or brackets. These consols, in the construction of the present wooden wharves, would increase the bearings of the wooden timbers to 5 feet, instead of the 3 feet allowed with the present method.

I conceived the idea of applying my reinforced concrete pile to the construction of quay walls after the conclusive experiments I had made at Novorossisk, Russia. My method enables me to reduce to a minimum the considerable working stock generally required for building under water, also the unforeseen contingencies so much dreaded in such undertakings.

After a long, careful study of the subject, I rejected the idea of driving in piles joined together, on acount of their excessive cost, and adopted a combination of reinforced concrete piles (square, rectangular or round, with or without longitudinal grooves) with reinforced concrete panels.

The same piles are used for constructing quay walls as for wharves. The shape is immaterial. A square pile, however, is easier to groove longitudinally on its two opposite faces. Said grooves allow the panels to slide between each two piles and can be made in such a manner that the panels will bind each pile to the next one.

Quay walls may be constructed in different ways:

(1) A sea wall along the harbor, Fig. 8, established at the request of the San Francisco Harbor Commission and as per specifications of Mr. Norton, chief engineer. This project comprises:

(A) A first row of piles, in which the panels slide. This row of piles is connected with a second row (called the steadying piles) by means of reinforced concrete beams, binding perpendicularly one pile of the first to the corresponding pile of the second row. These steadying piles are further connected with one another by a beam (B) running parallel to the first row.

Should one row of steadying piles not be sufficient, a second one can easily be established parallel to the first.

(2) Such a wall can also be constructed by means of parts "A" running parallel and connected with one another by beams

running perpendicularly from one to the other. In this case each part serves as a steadying line for the other.

After the work is completed, the space between the two rows can easily be filled up.

(3) *Construction of Moles.*—My method of constructing quay walls may also be applied to the erection of moles, and this is done by constructing a certain number of parts, "A," connected with one another laterally and perpendicularly.

The intervals can be filled up after completion of the work.

Other applications of this method may arise at any moment.

Whatever may be the requirements, the intervals can be filled up with the material brought up by the dredges, which may be working on each side of the walls in order to excavate to the necessary depth at the foot of same, and, in the case foreseen in description No. 2, vessels will be enabled to make fast on both sides of the wall.

One of the designs allows the construction of a wooden floor resting on wooden beams, whereas the other provides for a concrete floor resting on reinforced concrete beams.

The panels may be constructed of different thicknesses. (See 1, 2, 3, Fig. 8.)

In (1) the panels simply slide in the grooves of the piles. This form is used for the upper part of the wall only, where the lateral pressure of the adjacent ground is considerably less than nearer to the bottom.

In (2) the panels slide both in the grooves and along one of the faces of the pile. For a depth of 20 feet, as required for the harbor of San Francisco, (1) and (2), thus constructed, would be sufficient. Panel (2), having a thickness of $15\frac{3}{4}$ inches, must, at a depth of 20 feet, withstand a lateral pressure of about 1800 pounds per square foot.

In (3) the panels slide in grooves and along both faces of the piles. This form can be used for great depths.

In each case, and whatever may be the kind of panel required, the lower panel is supplied on its lower edge with a triangular steel shoe, in order to facilitate driving.

The succeeding panels overlap one another, and are bound together by means of semi-cylindrical flanges, which are made at the same time and on each side of the panels. Through these flanges are driven iron bars, one extremity of which is mortised. The mortises make it possible to securely fasten together the panels by means of cotters before they are immersed. After the cotters are

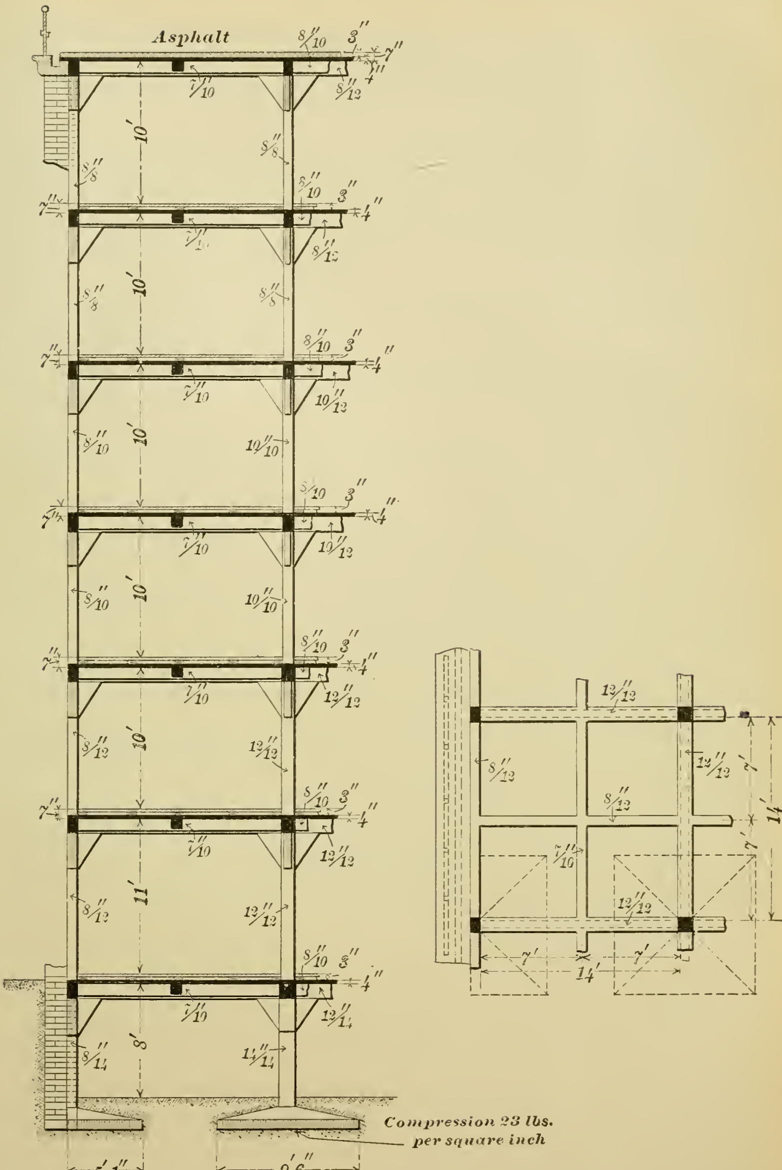


FIG. 9. CONCRETE-METAL BUILDING CONSTRUCTION. PERMANENT FLOOR LOAD, 60 POUNDS PER SQUARE FOOT.

driven in they, as well as the iron bars, are covered with cement in order to prevent oxidation.

The panels are bound to one another and immersed as soon as completed. The above-mentioned triangular steel shoe under the

action of the weight, which increases with every new panel, facilitates penetration through the mud. Such penetration can also be increased by having each part driven in by means of the hammer, the same as for the piles.

Buildings.—In the design of a seven-story building for San Francisco, Fig. 9, the somewhat large dimensions of the sleepers can be reduced by simply increasing the size of the iron bars imbedded in the concrete without increasing the thickness of the latter. (See plan No. 1.)

For this kind of construction, as also for any application of reinforced concrete beams or piles, there is no necessity of having:

(1) Any special size of iron, any joint or rivets; ordinary iron bars being sufficient.

(2) Any heavy or cumbersome hoisting machinery; a small elevator for conveying the iron, the cement and other material will be all that is required.

The advantages of reinforced concrete are many:

Supplies of material are easy to be had; no cumbersome material or machinery is required; rapidity in constructing; lightness; strength; equal or superior resistance as compared with brick or stone work, although both volume and weight are less; fireproof and waterproof qualities unexcelled, etc.

Besides reinforced concrete being much lighter, foundations will not need to be so deep and so strong as for ordinary brick buildings.

The incombustibility and the inalterability of reinforced concrete seem sometimes to be doubted, although these qualities have been proved by numerous and conclusive experiments.

OBITUARY.

George F. Allardt.

Member of the Technical Society of the Pacific Coast.

Another of the charter members of the Technical Society of the Pacific Coast has passed away.

George Frederick Allardt died on the 27th of July, 1903, in Oakland, near San Francisco.

Identified with engineering in California from the early development of the State, Mr. Allardt has been better known to the public than perhaps any other engineer on the Pacific Coast. From the time of his arrival here in 1858 up to the day of his death he was professionally active and variously employed. His work was connected with many of the enterprises that have been the most prominent of the far West. The early period of our State's history called for men that were resourceful, adaptable and of the greatest energy. Their field of labor was extensive in the most daring application of the term, and almost entirely unprepared; analogous cases were lacking when these men were called upon to undertake vast propositions with the most meager facilities, throwing them entirely upon their own mental fertility to devise not only the design of the project itself but also to prepare the ways and means for carrying it out successfully.

Allardt passed through this trying period. He was one of the pioneer engineers of the State of California, and as such will always be remembered. His labors, carried on almost uninterruptedly to the day of his death, deserve the fullest recognition, and the Technical Society takes great pride in now pointing to this honorable career and proclaiming him one of the old guard, who will never be forgotten by those who had the good fortune to know him.

Through many years he was a very active member of the Society, one who never shirked any of the responsibilities and duties requested of him. It is well remembered that in the formation and organization of a representative body of civil engineers in California, a movement emanating from the Technical Society, Mr. Allardt labored for many days in the framing of a constitution and regulations which were to be a guide to the profession and intended to place it upon a higher basis.

In all such matters his counsel and advice, based upon his long and valuable experience, were freely given to his colleagues

at all times, and whatever he did in this way was done with such a cheerful manner and with a certain inimitable humor that made his presence wherever wanted not only a great profit but a great pleasure.

There was certainly never a more congenial companion. He had the rare faculty of an absolutely even temper, and in his intercourse with his fellow-men he showed but one side,—that bright and cheerful disposition which was natural to him.

What he has performed professionally will always speak for itself. It was well done, and it is well known to those who with him have been residents of the Golden State from its earlier romantic history.

A few of the main points of his busy career have been touched upon by his son, Mr. C. F. Allardt, who has courteously furnished the Technical Society with the following short sketch:

"George Frederick Allardt, born February 1, 1833, in Lauban, Prussia, was descended from Huguenot ancestors, who went into Germany at the time of the expulsion of the Huguenots from France. His father was a minister of the German Reformed Church. When George was six months old, the family came to America and settled in Cleveland, Ohio, where his father had charge of the German Church, and where the boy received his education. After he had graduated from the high school he went into a drug store to learn the drug business. This business proving hard on his health, he began the study of civil engineering, and soon obtained a position on the Cleveland, Painesville and Ashtabula Railway. He was also employed for a time in the office of the city engineer, of Cleveland.

"In 1858 he came to California by way of the isthmus. His first work here was as a draughtsman for the San Francisco and San José Railway. He was also in the office of the surveyor general, and surveyed many Spanish grants. In 1863 he went to the East for a visit at his old home. In the same year he returned and went to the Reese River country during the mining excitement, surveying mines and doing a general surveying business. In 1865 he went to Cleveland and married Miss Emma Kluegel, whom he brought to California and with whom he settled in San Francisco.

"In 1865 the Harbor Commissioners offered a prize for the best plan for a sea wall for San Francisco. Mr. Allardt's plans were adopted, and the sea wall is now built according to these plans.

"In 1868 Mr. Allardt was appointed chief engineer of the Tide Land Commission, and while holding this position he surveyed all

the tide lands in San Francisco Bay. He held this position for seven years.

"In 1876 he was appointed assistant engineer on the commission to investigate all the available water supplies for the city of San Francisco, and thus became thoroughly familiar with the water question. He next became engineer for the farmers in the Debris suit between the farmers and miners. This lasted for a number of years, and was won by the farmers. In 1889 he went to Honolulu, and reported on the irrigation of sugar lands on the islands of Oahu and Kauai. His report was followed, and there are now many plantations pumping water for irrigation purposes with great success. In 1890 he made another trip to Honolulu to make plans for a sewerage system and for deepening the bar of Honolulu Harbor. These works were carried out.

"In 1892 he was appointed the surveyor for the partition of the San Pablo Rancho (Emeric *vs*. Alvarado). This was in the courts thirty years, the land involved consisting of over 17,000 acres. He was engaged in this work about three years. This was the largest survey of its kind ever made in California.

"He experted for the Spring Valley Water Works in their law-suits, being the company's chief witness. He was also one of the experts for the city of Oakland in suit against the Contra Costa Water Company in 1900.

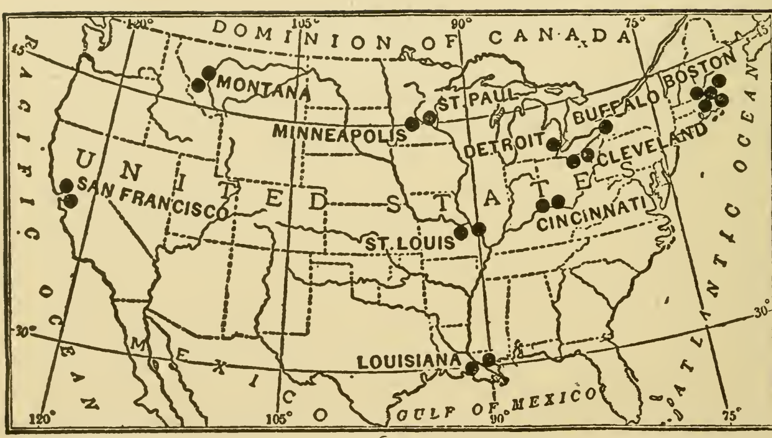
"He made a specialty of hydraulic engineering. Besides the more important work mentioned above, he did a great deal of work in all lines of civil engineering, including plans for sewerage systems, irrigating projects, water works and land surveying, having his office in San Francisco.

"Twenty years ago he foresaw, from his intimate knowledge of topographical conditions, that Point Richmond would become a great railway terminus, and he acquired a large interest in the tide lands there at that time.

"His life companion, his faithful wife, survives him, as do also three children, Charles F. Allardt, Frederick A. Allardt and Lotta Allardt."

And now that this useful life is ended our Society expresses its deepest sympathy with the family of our departed member, and resolves to hand this token of its sense of loss in the death of George F. Allardt to his widow, with the assurance that we, too, have lost a friend and counselor.

Otto von Geldern,
Committee.


DOMINION OF CANADA
PACIFIC OCEAN
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BOSTON
DETROIT
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90°
75°
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RAINFALL AND RUN-OFF OF NEW ENGLAND, ATLANTIC COAST AND SOUTHWESTERN COLORADO STREAMS.

BY WILLIAM O. WEBBER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 16, 1903.*]

YOUR President has asked the writer to submit the tables in regard to the flowage of the New England and Eastern streams recently compiled in connection with an important case where the amount of water taken from a manufacturing concern was of vital interest as a measure in part of the damages sustained by such taking. As a result of the testimony submitted in this case by numerous engineers on both sides, the writer is of the opinion that too much stress has been laid upon the records of Sudbury River, as universal measure of the flowage of streams in this vicinity, and also that not enough consideration is given to the *character* of watersheds in contradistinction to the *area* of watersheds in regard to the amount of water per square mile contributed at different seasons of the year. There is no doubt that the measurements of the Sudbury River are eminently safe measurements to take when computing the possibilities of contribution from a similar watershed for town waterworks and other municipal purposes, where it is very essential that the minimum amount obtainable is the measure of the development and the value of the watershed for such purpose. It then becomes analogous to the letters which one of the United States Fish Commissioners used to receive in regard to the propagation of trout. Many of these letters inquired how many trout could be raised upon a stream which was absolutely

*Manuscript received September 3, 1903.—Secretary, Ass'n of Eng. Socs.

dry for only six weeks in the year, and of course the answer is apparent. This, however, is not true of the use of a stream for manufacturing purposes. It would be unwise to restrict the development of a stream for manufacturing purposes to the minimum amount which might be contributed in the driest period of an extremely dry season, as this would probably occur only once in every four or five years. It therefore becomes pertinent to ascertain what the probable low flow of a certain stream may be in an ordinary season with proper conservation and reservoirs, and before the extent of such reservoir systems can be estimated a study of the probable average contribution of the watershed supplying such stream must be made. To obtain such information by actual measurements of the stream in question would require a series of observations extending over so long a period as to practically prohibit the development of the stream, and measurements taken for a short period only are practically worthless, except as an indication when taken into consideration with the contribution of other developed streams for the same period, where the known amount of power usually available on the developed stream is easily ascertained. The writer therefore submits the following tables, in the hope that it may throw some light on the subject and at least cause some discussion. Knowing full well that the data do not extend over nearly so long periods as might be desirable, and while admitting that their purpose was for comparison with the stream then in question, of which only a limited amount of data was available, still, in the light of other figures with which he is familiar, and which he hopes to have the privilege of submitting later, and which corroborate his opinions, he hopes that they may throw some further light on the subject.

First, in reference to table marked XXIII, it will be noticed that the mean contribution in cubic feet per square mile is remarkably uniform, and is oftentimes much larger on a small watershed than on a larger watershed. The minimum is usually larger on a large watershed than on a small watershed, and the maximum per square mile is usually larger on a small watershed than on a large watershed, but so much depends on the character of the watershed that the writer believes that each watershed should be carefully studied in all its aspects before all its deductions can be made with any certainty.

The table marked I would seem to indicate that in New England and Eastern streams in dry years about $1\frac{1}{4}$ cubic feet per second per square mile could be relied upon, whereas in wet years

at least $1\frac{3}{4}$ is available, and in the five dry months of dry years about $\frac{1}{2}$ cubic foot per square mile is available, as against double that amount in the five dry months of wet years.

Tables II, III and IV are intended to show the percentages of the rainfall collected in different streams during the dry months of the year, and also during the whole year for wet and dry seasons. These tables would seem to show that in wet years we might reasonably expect to collect 25 per cent. of the rainfall in the five dry months, whereas in dry years from 10 per cent. to 15 per cent. is all that can be expected on small streams and 20 per cent. on larger streams. In wet years we may expect to collect 57 per cent. of the rainfall. In average years 45 per cent. and in dry years 32 per cent., while the maximum per cent. is found to run as high as 70 per cent.

In the tables presented the years 1894 and 1896 were about average years. The year 1895 was rather a dry year, and the years 1897 and 1898 were wet years.

Mr. James B. Francis, the eminent hydraulic engineer, once told the writer that 1 cubic foot per second per square mile would represent the maximum safe development of a stream for power and manufacturing purposes, and in the table marked XX the writer has deduced that the absolutely safe development of a stream would be at the rate of .567 cubic foot per second per square mile. The average flow of streams for the five dry months of wet seasons is 1.435 per cubic foot per second per square mile. The average of these gives the 1 cubic foot per second per square mile which Mr. Francis considered as the maximum rate for commercial development.

It is interesting to compare this with the table marked XXI, based on the average collection per month, arranged in regard to the dryness of months and based on the average rainfall in this vicinity from 1818 to 1897, inclusive. This again shows 1 cubic foot per second for the six dry months, which, curiously enough, in this table occurs in the month of June, and corroborates again an old saying of Mr. Francis that "June flow" in an average year might safely be taken as the average commercial flow of a stream.

The writer has measured the flow of many streams in this country, going as far west as the San Miguel, in Southwestern Colorado, as far north as the Ontonagon, in the Northern Michigan Peninsula, and as far south as the Catawba, in South Carolina. The data thus collected strengthen his opinion in regard to the results of stream measurements, and it should be clearly understood that the accompanying tables and deductions refer only to

New England and other Eastern Atlantic Coast streams, as the conditions governing streams in other sections of the country are entirely different, owing to the climatic conditions, so that the maximum flow of the Rocky Mountain streams usually occurs at the time of the minimum flow of our streams in New England, and yet the same general principles seem to govern all of the results, and, in the writer's opinion, the only way in which to form an accurate opinion as to the proper development of any stream is to study that particular stream in relation to its own watershed and the average rain-fall and run-off found by collecting actual data in the immediate vicinity.

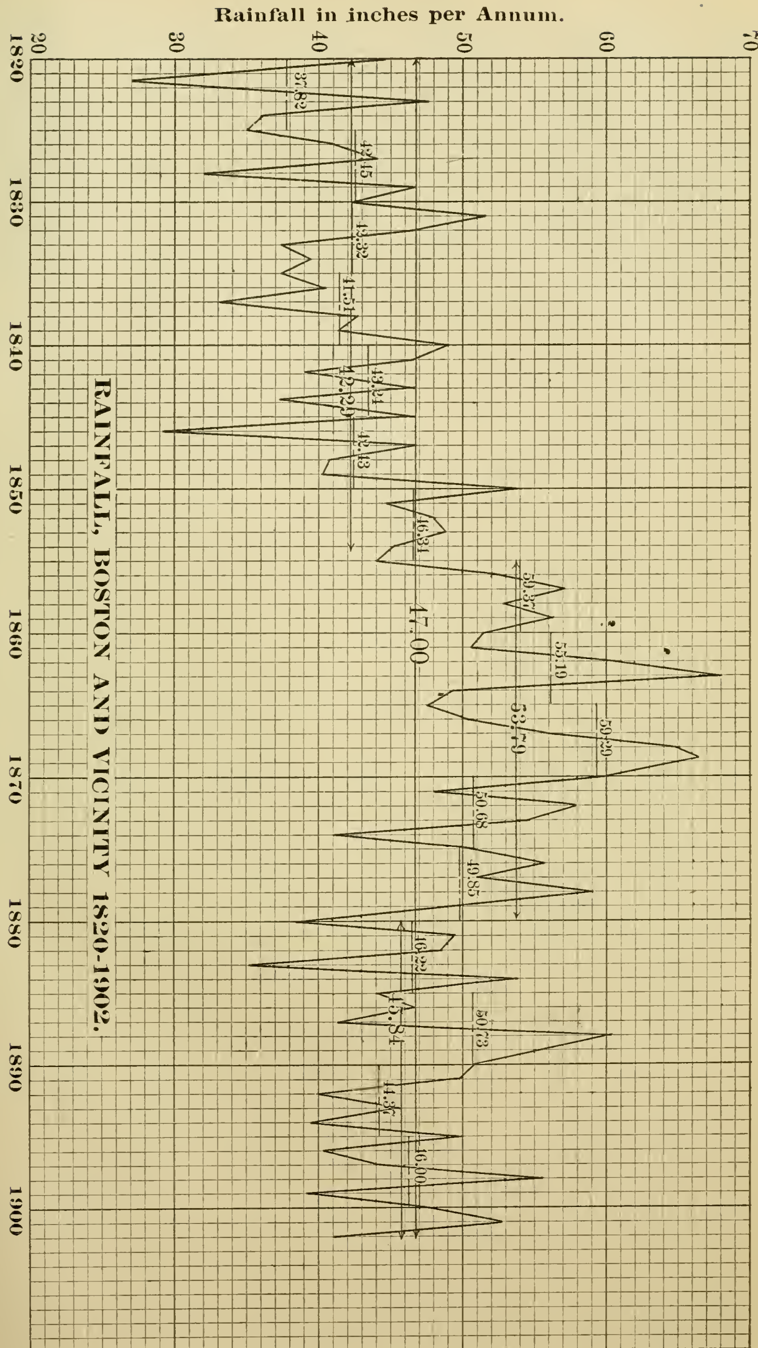
In the Rocky Mountain regions the amount of rainfall varies very much with the altitude, there being a steady increase of rainfall as the altitude increases up to a certain point, and then a remarkably rapid falling off or entire cessation of rainfall. Very little rain falls above the timber line, and, in fact, the only contributions of moisture above that elevation is largely due to the snow which is blown up horizontally from the lower elevations. The average rainfall in Colorado, west of the Rocky Mountains, on the Mesa, which lies at an elevation of about 7000 feet, is fifteen inches. This increases as the higher altitudes are reached, so that at Telluride, Ruby, Summit and other points averaging about 10,000 feet elevation the average rainfall is about 26 inches.

The freshets in these streams occur in July, when the large deposits of snow in the crevices and ravines on the upper mountain regions begin to melt, and it is usually not until September that these great deposits of snow and ice are practically all melted away. The low flow of the streams occurs in January, February and March, when everything is entirely frozen up.

There is also another phenomenon in connection with the Western Rocky Mountain streams, in that large quantities of water deposited in the upper mountain regions disappear before reaching the Mesa, and reappear again in the lower canons through underground passages.

The writer is of the opinion that there is more general misinformation prevalent as to the amount of water available in these watersheds bounding the arid region of the Southwest than is usually conceded, and that very many of the irrigation schemes are doomed to commercial failure for reason of insufficient data.

The Government has maintained very few rain gauges at extremely high altitudes, as this means isolation to the observer for a period usually covering six months.



RAINFALL, BOSTON AND VICINITY 1820-1902.

The writer is of the opinion that at some later date it might interest the Society to hear parts of a report on an irrigation scheme to bring out some of the engineering features involved.

In the Northern Michigan Peninsula, where the run-off is largely influenced by the proximity of the Great Lakes, another set of conditions prevails. The rainfall is extremely large, owing to the fact that the country is largely covered with forests and swamps, lying at a comparatively slight elevation above that of the lakes, so that the fall in the average streams is remarkably slight and the amount of water held back and stored is very large.

TABLE I.

COMPARISON OF THE FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN WET AND DRY YEARS.

Dry Years.

	Cochituate.		Sudbury.		Mystic.		Merrimac.		Connecticut.		Perkiomen.		Neshaminy.		Tohickon.	
	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.
1894	0.46	0.96	0.55	1.19	0.61	1.06	0.84	1.15	0.65	0.97	......	......	......	......	......	......
1895	0.55	1.49	0.42	1.79	0.61	1.28	0.53	1.28	0.64	1.19	0.43	1.15	0.49	1.20	0.37	1.38
1896	0.57	1.48	0.40	1.58	0.58	1.44	0.69	1.47	0.64	......	0.69	1.26	0.52	1.25	0.76	1.46
Average, 5 months .	0.53	......	0.46	......	0.60	......	0.68	......	0.64	......	0.56	......	0.50	......	0.56	......
Average, year . . .	......	1.31	......	1.52	......	1.26	......	1.30	......	1.08	......	1.20	......	1.22	......	1.42

Wet Years.

	Cochituate.		Sudbury.		Mystic.		Merrimac.		Connecticut.		Perkiomen.		Neshaminy.		Tohickon.	
	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.	5 mos.	Year.
1888	1.15	2.29	1.14	2.62	1.04	2.30	1.86	2.91	1.85	2.00	1.19	2.21	0.74	2.10	1.42	2.93
1894	......	......	......	......	......	......	......	......	......	......	1.82	1.87	2.01	1.90	2.23	3.29
1897	0.78	1.25	1.12	1.74	1.03	1.47	1.81	......	......	......	1.28	1.45	1.66	1.56	1.72	1.79
Average, 5 months .	0.96	......	1.13	......	1.02	......	1.83	......	1.85	......	1.43	......	1.47	......	1.79	......
Average, year . . .	.. ...	1.77	......	2.18	......	1.88	......	2.91	......	2.00	......	1.84	......	1.85	......	2.34

TABLE II.

Percentages of Rainfall Collected.

Connecticut River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	217.0	70.3	15.2	23.2	16.0	41.1	1873
	146.9	65.4	38.2	33.8	26.7	28.9	1874
	113.8	29.8	22.9	22.8	30.4	22.8	1878
Sum. .	477.7	165.5	76.3	79.8	73.1	92.8	. . .
Avg. .	159.2	55.2	25.4	26.6	24.4	35.9	. . .

Dry Years.

	96.3	32.3	15.70	19.5	15.4	18.6	1880
	97.6	33.6	21.20	24.0	39.4	18.2	1881
Sum. .	193.9	65.9	36.90	43.5	54.8	36.8	. . .
Avg. .	96.9	32.9	18.45	21.7	27.4	18.4	. . .

Cochituate River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	82.2	119.1	15.1	19.5	29.8	33.4	1873
	81.7	40.8	30.0	19.1	34.3	50.3	1874
	112.0	47.3	13.2	27.1	32.0	18.7	1887
	51.2	25.8	28.1	14.9	26.2	51.9	1888
	32.9	37.1	17.9	75.0	36.4	49.6	1889
	34.9	79.1	14.2	13.9	21.6	33.7	1890
Sum. .	394.9	349.2	118.5	169.5	180.3	237.6	. . .
Avg. .	65.8	58.2	19.7	28.2	30.0	39.6	. . .

Dry Years.

	22.2	4.5	4.7	6.1	14.3	16.6	1880
	39.6	27.0	5.8	7 6	10.8	6.4	1881
	32.8	33.1	1.7	6.2	10.5	37.9	1882
	31.9	3.7	0.6	18.6	47.4	11.5	1883
	47.6	14.4	0.0	4.8	15.5	15.0	1885
	43.0	35.5	11.1	7.8	10.7	13.4	1886
Sum. .	217.1	118.2	23.9	51.1	109.2	100.8	. .
Avg. .	36.2	19.7	3.9	8.5	18.2	16 8	. . .

TABLE III.

Percentages of Rainfall Collected.

Mystic River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	104.9	24.5	22.6	12.8	29.7	44.2	1879
	50.7	29.9	33.3	51.9	14.1	13.6	1881
	112.0	47.3	13.2	27.1	32.0	18.7	1887
	59.6	38.1	17.5	8.8	15.3	55.3	1888
	46.9	57.0	15.8	52.2	22.5	33.7	1889
	47.6	56.9	19.0	12.7	15.6	29.5	1890
Sum. .	418.7	253.7	121.4	165.5	129.2	195.0	. . .
Avg. .	69.8	42.3	20.2	25.9	21.5	32.5	. . .

Dry Years.

	47.3	34.3	9.2	14.7	31.7	13.5	1880
	40.4	38.6	14.9	20.8	6.3	30.0	1882
	33.5	31.8	10.8	25.7	12.1	7.2	1883
	43.0	35.5	11.1	7.8	10.7	13.4	1886
	57.0	22.8	13.3	11.3	19.3	12.1	1891
	25.3	125.8	14.2	15.1	14.3	10.5	1894
Sum. .	246.5	288.8	73.5	95.4	94.4	86.7	. . .
Avg. .	41.1	48.1	12.2	15.9	15.7	14.4	. . .

Sudbury River.

Wet Years.

	May.	June.	July.	August.	September.	October.	Year.
	59.5	24.0	16.0	12.8	10.4	23.8	1875
	49.0	42.8	21.0	19.4	13.0	11.2	1881
	60.3	28.7	14.9	10.9	23.2	71.4	1888
	53.4	40.3	12.6	61.2	30.9	51.6	1889
Sum. .	222.1	135.8	64.5	104.3	77.5	158.0	. . .
Avg. .	55.5	33.9	16.1	26.1	19.4	39.5	. . .

Dry Years.

	50.0	14.2	5.0	5.3	8.6	4.8	1880
	40.0	21.6	7.7	19.1	10.4	5.9	1883
	42.9	23.9	6.3	4.1	7.0	8.0	1886
	154.5	26.9	5.5	7.2	14.5	12.0	1887
	51.7	18.9	7.8	6.1	14.7	9.8	1891
	77.8	31.9	11.0	5.9	10.8	9.7	1893
Sum. .	416.9	137.4	43.3	47.7	66.0	50.2	. . .
Avg. .	69.5	22.9	7.2	7.9	11.0	8.3	. . .

Percentage Collected in Wet Year—1888.

Cochituate	54.4
Sudbury	62.2
Mystic	54.8
	171.4
Average	57.13

Percentage Collected in Dry Year—1883

Cochituate	32.4
Sudbury	34.1
Mystic	29.8
	96.3
Average	32.1

Percentage Collected—Average Year.

Cochituate	43.12—1863-95
Sudbury	48.00—1875-95
Mystic	44.60—1878-95
	135.72
Average	45.24

Maximum Percentage Collected.

Cochituate	69.1%—1891
Sudbury	62.2%—1888
Mystic	60.3%—1891
	191.6%
Average	63.87%

TABLE IV.

Average Percentage of Collections.

	May.	June.	July.	August.	September.	October.
Connecticut . .	132.2	36.5	21.30	21.8	29.30	28.30
Potomac	46.3	36.8	20.50	20.5	27.50	45.70
Merrimac . . .	141.0	32.3	22.20	27.6	37.80	37.50
Cochituate . . .	53.5	32.6	13.89	17.2	29.94	27.16
Mystic	69.1	39.0	17.10	18.6	20.10	20.50
Summary . . .	442.1	176.9	94.99	105.70	144.64	159.16
Average	88.4	35.4	18.99	21.14	28.93	31.83

Summary of Percentage of Rainfall Collected.

Wet Years.

	May.	June.	July.	August.	September.	October.
Connecticut . .	159.2	55.2	25.4	26.6	24.4	30.9
Mystic	69.8	42.3	20.2	25.9	21.4	32.5
Sudbury	55.5	33.9	16.1	26.1	19.4	39.5
Cochituate . . .	65.8	58.2	19.7	28.2	30.0	39.6
Summary . . .	350.3	189.6	81.4	106.8	95.2	142.5
Average	87.4	47.4	20.7	24.7	23.8	35.6

Summary of Percentage of Rainfall Collected.

Dry Years.

	May.	June.	July.	August.	September.	October.
Connecticut . .	96.9	32.9	18.4	21.7	27.4	18.4
Mystic	41.4	48.1	12.2	15.9	15.7	14.4
Sudbury	69.5	22.9	7.2	7.9	11.0	8.3
Cochituate . . .	36.2	19.7	3.9	8.5	18.2	16.8
Summary . . .	244.0	123.6	41.7	54.0	72.3	57.9
Average	61.0	30.9	10.4	13.5	18.1	14.5

TABLE V.

COMPARISON IN THE FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN THE MONTHS OF JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER.

	1894. 5 Months, June–October.		1895. 5 Months, June–October.		1896. 5 Months, June–October.		1897. 5 Months, June–October.	
	Average.	Total.	Average.	Total.	Average.	Total.	Average.	Total.
Cochituate	0.416	2.070	0.721	3.605	0.682	3.41	0.737	3.685
Sudbury	0.406	2.030	0.651	3.255	0.474	2.37	0.868	4.340
Mystic	0.480	2.400	0.626	3.130	0.606	3.03	0.786	3.930
Merrimac	0.634	3.170	0.622	3.110	0.670	3.35	1.468	7.342
Connecticut	0.510	2.550	0.454	2.270	0.676	3.38	......	......
Perkiomen	0.950	4.750	0.300	1.500	0.866	4.33	0.630	3.150
Neshaminy	0.987	4.935	0.385	1.925	0.620	3.10	1.216	6.080
Tohickon	1.107	5.535	0.274	1.375	0.888	4.44	0.932	4.660
Average	0.686	3.430	0.504	2.521	0.685	3.42	0.829	4.148
Average of Cochituate, Mystic and Sudbury	0.434	......	0.666	......	0.587	......	0.797	0.621

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS.

	1894.				1895.				1896.		
	Average of 5 months, May–Sept.	Total of 5 months, May–Sept.	Average for year.	Total for year.	Average of 5 months, May–Sept.	Total of 5 months, May–Sept.	Average for year.	Total for year.	Average of 5 months, May–Sept.	Average for year.	Total for year.
Sunbury	0.55	2.75	1.19	14.28	0.420	2.10	1.79	21.48	0.404	1.582	18.99
Mystic	0.61	3.05	1.06	12.74	0.610	3.05	1.28	15.42	0.580	1.442	17.30
Merrimac	0.84	4.22	1.15	13.80	0.530	2.66	1.28	15.36	0.690	1.466	17.59
Connecticut	0.65	3.28	0.97	11.65	0.640	3.23	1.19	14.32	0.640	......	......
Perkiomen	1.82	9.10	1.77	21.20	0.430	2.15	1.15	13.86	0.690	1.265	15.18
Neshaminy	2.01	10.05	1.90	22.83	0.490	2.45	1.20	14.37	0.520	1.250	15.00
Tohickon	2.23	11.15	2.29	27.50	0.370	1.85	1.88	16.55	0.760	1.464	17.57
Cochituate	0.46	2.30	0.96	11.50	0.550	2.75	1.49	17.85	0.568	1.485	17.82
Average	1.14	......	1.41	......	0.505	......	1.34	......	0.606	1.422	......

TABLE VI.

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS.

	1888.				1897.			
	Average of five months, May-Sept.	Total of five months, May-Sept.	Average for year.	Total for year.	Average of five months, May-Sept.	Total of five months, May-Sept.	Average for year.	Total for year.
Cochituate	1.15	5.75	2.29	27.40	0.78	3.88	1.25	15.09
Sudbury	1.14	5.70	2.62	31.44	1.12	5.60	1.74	20.82
Mystic	1.04	5.20	2.30	27.54	1.03	5.15	1.47	17.64
Merrimac	1.86	9.29	2.91	34.92	1.81	9.07	......	....
Connecticut	1.85	9.28	2.00	24.01	......	......	......	....
Perkiomen	1.19	5.95	2.21	26.53	1.28	6.40	1.45	17.40
Neshaminy	0.74	3.70	2.10	25.20	1.66	8.30	1.56	18.74
Tohickon	1.42	7.10	2.93	35.20	1.72	8.60	1.79	21.51
Average	1.30	......	2.42	......	1.34	......	1.54	......

FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	1.21	1.07	0.65	0.54	0.41	0.37	4.89	......
Sudbury	1.41	1.49	1.51	0.91	0.28	0.15	5.75	......
Mystic	1.59	1.96	0.44	0.83	0.36	0.34	5.52	......
Perkiomen	3.45	0.83	1.35	0.52	0.26	0.19	6.60	......
Neshaminy	2.38	2.21	0.52	0.96	0.20	0.14	8.46	......
Tohickon	4.03	1.54	2.32	0.63	0.11	0.06	8.69	......
Average	2.34	1.51	1.47	0.73	0.27	0.21	6.65	1.11

TABLE VII.

FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	1.210	1.41	1.59	3.45	2.38	4.03	2.214
June	1.070	1.49	1.96	0.83	2.21	1.54	2.782
July	0.650	1.51	0.44	1.35	2.57	2.32	2.363
August	0.545	0.91	0.83	0.52	0.96	0.63	1.110
September	0.410	0.28	0.36	0.26	0.20	0.11	0.604
October	0.370	0.15	0.34	0.19	0.14	0.06	0.483
Average, 5 months, May-September	0.777	1.12	1.03	1.28	1.66	1.72	1.814
Average, 6 months, May-October	0.710	0.96	0.92	1.10	1.41	1.45	1.592
Average, 5 months, June-October	0.610	0.87	0.77	0.63	1.22	1.93	1.468

COMPARISON OF RAINFALL COLLECTED IN EASTERN STREAMS, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1897.

PER CENT. COLLECTED.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	32.80	27.80	15.70	19.20	17.80	48.60	26.98
Sudbury	37.34	37.29	21.56	30.00	10.73	35.74	28.77
Mystic	37.04	38.45	13.14	27.62	13.08	99.23	38.09
Perkiomen	46.00	29.00	20.00	22.00	18.00	11.00	23.90
Neshaminy	36.00	47.00	33.00	32.00	16.00	7.00	28.33
Tohickon	52.00	33.00	32.00	19.00	6.00	4.00	24.33
Average	40.03	35.42	22.56	24.80	13.60	33.93	28.40

TABLE VIII.

PER CENT. COLLECTED, 1897.

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	32.8	37.34	37.04	45.0	36.00	52.00	56.00
June	27.8	37.29	38.45	29.0	47.00	33.00	51.70
July	15.7	21.56	13.14	20.0	33.00	32.00	40.40
August	19.2	30.00	27.62	21.0	32.00	19.00	37.60
September	17.8	10.73	13.08	18.0	16.00	6.00	35.00
October	48.6	35.74	99.23	10.0	6.00	4.00	63.60
Average, 5 mos., May-September	22.66	27.38	25.87	26.6	32.80	28.40	44.10
Average, 6 mos., May-October	26.98	28.77	38.09	23.9	28.33	24.33	47.40
Average, 5 mos., June-October	25.82	27.06	38.30	19.6	26.80	18.80	45.66

TABLE IX.

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1896.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	0.54	0 64	0.32	0.410	0.93	1.110	3.95	......
Sudbury	0.56	0.62	0.15	0.090	0.60	0.910	2.93	......
Mystic	0.67	0.68	0.34	0.290	0.95	0.770	3.70	......
Perkiomen	0.40	0.43	1.74	0.290	0.59	1.280	4.73	......
Neshaminy	0.33	0.36	0.90	0.170	0.86	0.810	3.43	......
Tohickon	0.27	0.16	2.20	0.160	1.00	0.920	4.71	......
Average	0.46	0.48	0.94	0.235	0.82	0.966	3.91	0.65

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1896 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.	Connecticut.
May	0.540	0.560	0.670	0.400	0.33	0.27	1.149	1.195
June	0.640	0.620	0.680	0.430	0.36	0.16	0.770	0.661
July	0.320	0.150	0.340	1.740	0.90	2.20	0.433	0.451
August	0.410	0.090	0.290	0.290	0.17	0.16	0.446	0.366
September	0.930	0.600	0.950	0.590	0.86	1.00	0.668	0.547
October	1.110	0.910	0.770	1.280	0.81	0.92	1.036	1.334
Average, 5 months—May-Sept.	0.568	0.404	0.580	0.690	0.52	0.76	0.693	0.644
Average, 6 months—May-Oct.	0.660	0.490	0.620	0.790	0.57	0.78	0.750	0.762
Average, 5 months—June-Oct.	0.682	0.474	0.606	0.866	0.62	0.89	0.670	0.676

TABLE X.

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1896. Per Cent. Collected.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	27.50	23.5	16.9	19.4	12.5	36.40	22.7
Sudbury	24.90	21.4	6.8	4.3	8.7	28.00	15.7
Mystic	38.50	31.9	16.2	12.9	13.5	27.50	23.6
Perkiomen	12.00	11.0	21.0	28.0	12.0	31.00	19.1
Neshaminy	13.00	9.0	20.0	21.0	16.0	35.00	19.0
Tohickon	10.00	4.0	32.0	11.0	19.0	40.00	19.3
Average	20.98	16.8	18.8	16.1	13.6	32.98	19.9

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1896. Per Cent. Collected (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	27.5	24.9	38.5	12.0	13.0	10.0
June	23.5	21.4	31.9	11.0	9.0	4.0
July	16.9	6.8	16.2	21.0	20.0	32.0
August	19.4	4.3	12.9	28 0	21.0	11.0
September	12.5	8.8	13.5	12.0	16.0	19.0
October	36.4	28.0	27.5	31.0	35.0	40.0
Average, 5 months, May-September	19.9	13.2	22.6	16.8	16.0	15.2
Average, 6 months, May-October	22.7	15.7	23.6	19.1	19.0	19.3
Average, 5 months, June-October	21.7	13.8	20.4	20.6	20.2	21.2

TABLE XI.

COMPARISON OF EASTERN STREAMS. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE, SIX MONTHS—MAY, JUNE, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1895.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	0.84	0.36	0.480	0.435	0.620	1.710	4.440	......
Sudbury	0.98	0.27	0.360	0.360	0.135	2.130	4.230	......
Mystic	1.14	0.45	0.480	0.670	0.290	1.240	4.270	......
Perkiomen	0.85	0.38	0.530	0.240	0.150	0.200	2.350	......
Neshaminy	0.62	0.46	0.765	0.570	0.050	0.070	2.540	......
Tohickon	0.57	0.24	0.700	0.310	0.040	0.080	1.940	......
Average	0.83	0.36	0.550	0.430	0.214	0.905	3.289	0.548

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	0.840	0.980	1.140	0.85	0.620	0.570	0.47
June	0.360	0.270	0.450	0.38	0.460	0.240	0.69
July	0.480	0.360	0.480	0.53	0.760	0.700	0.60
August	0.438	0.360	0.670	0.24	0.580	0.310	0.47
September	0.620	0.135	0.290	0.15	0.050	0.040	0.43
October	1.710	2.130	1.240	0.20	0.070	0.080	0.92
Average for 5 months, May-September	0.550	0.42	0.610	0.43	0.490	0.370	0.530
Average for 6 months, May-October	0.740	0 71	0.710	0.39	0.420	0.320	0.600
Average for 5 months, June-October	0.721	0.65	0.626	0.30	0.385	0.274	0.622

TABLE XII.

Comparison of Rainfall Collected in Eastern Streams, 1895. Per Cent. Collected.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	47.8	13.0	11.8	12.6	25.0	20.6	21.8
Sudbury	56.1	10.8	8.2	9.9	6.7	23.0	19.1
Mystic	41.5	13.7	12.8	14.1	15.7	14.0	18.6
Perkiomen	28.0	12.0	15.0	8.0	18.0	7.0	14.6
Neshaminy	27.0	12.0	23.0	20.0	7.0	3.0	15.3
Tohickon	22.0	6.0	23.0	8.0	5.0	2.0	11.0
Average	37.1	11.2	15.6	12.1	12.9	11.6	13.4

Comparison of Rainfall in Eastern Streams, 1895. Per Cent. Collected (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	47.8	56.1	41.5	28.0	27.0	22.0
June	13.0	10.8	13.7	12.0	12.0	6.0
July	11.8	8.2	12.8	15.0	23.0	23.0
August	12.6	9.9	14.1	8.0	20.0	8.0
September	25.0	6.7	15.7	18.0	7.0	5.0
October	20.6	23.0	14.0	7.0	3.0	2.0
Average for 5 months, May-September	22.0	18.3	19.6	16.2	18.0	13.0
Average for 5 months, June-October	16.8	11.7	14.1	12.0	13.0	8.8
Average for 6 months, May-October	21.8	19.1	18.6	14.6	15.0	11.0

TABLE XIII.

Inches of Rainfall Collected, Average Year, 1895.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	0.97	0.40	0.55	0.50	0.690	1.970	5.08	......
Sudbury	1.13	0.30	0.41	0.41	0.150	2.460	4.86	......
Mystic	1.31	0.50	0.55	0.77	0.320	1.430	4.88	......
Average	1.14	0.40	0.50	0.56	0.386	1.953	4.94	0.823

Flow in Cubic Feet per Second per Square Mile, 1895.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Genesee	0.19	0.13	0.11	0.12	0.10	0.44	1.09	......
Hudson	1.76	0.70	0.66	1.00	0.65	0 69	5.46	......
Merrimac	0.47	0.69	0.60	0.47	0.43	0.92	3.58	......
Connecticut	1 43	0.75	0.35	0.38	0.32	0.47	3.70	......
Average	0.96	0.55	0.43	0.49	0.37	0.63	3.46	0.576

TABLE XIV.

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September, October, 1894.

	May.	June.	July.	August.	September	October.	Summary.	Average.
Cochituate	0.79	0.40	0.330	0.360	0.41	0.57	2.86	......
Sudbury	1.30	0.65	0.250	0.320	0.23	0.58	3.33	......
Mystic	1.14	0.82	0.430	0.330	0.32	0.50	3.54	......
Perkiomen	5.78	1.01	0.500	0.300	1.50	1.44	10.53	......
Neshaminy	6.42	0.95	0.370	0.295	2.03	1.29	11.35	......
Tohickon	7.43	0.47	0.165	0.100	2.98	1.82	12.96	......
Average	3.81	0.72	0.340	0.280	1.24	1.03	7.43	1.24

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September, October, 1894 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	0.790	1.300	1.140	5.78	6.420	7.430	1.550
June	0.400	0.650	0.820	1.01	0.950	0.470	1.400
July	0.330	0.250	0.430	0.50	0.370	0.165	0.500
August	0.360	0.320	0.330	0.30	0.295	0.100	0.370
September	0.410	0.230	0.320	1.50	2.030	2.980	0.400
October	0.570	0.580	0.500	1.44	1.290	1.820	0.500
Average for 5 months, May-September	0.460	0.550	0.610	1.82	2.010	2.230	0.840
Average for 6 months, May-October	0.480	0.550	0.590	1.75	1.890	2.160	0.780
Average for 5 months, June-October	0.416	0.406	0.480	0.95	0.980	1.107	0.634

TABLE XV.

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1894.

Per Cent. Collected.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	24.6	27.9	10.4	16.1	20.0	12.8	18.6
Sudbury	35.4	62.6	8.8	18.4	9.8	12.5	27.9
Mystic	25.3	125.8	14.2	15.1	14.3	10.5	33.9
Perkiomen	57.0	31.0	20.0	15.0	26.0	27.0	29.0
Neshaminy	55.0	41.0	11.0	13.0	28.0	28.0	29.0
Tohickon	63.0	20.0	8.0	6.0	35.0	41.0	29.0
Average	43.4	51.5	12.0	13.9	22.2	21.9	27.5

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1894.

Per Cent. Collected (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	24.6	35.4	25.3	57.0	55.0	63.0
June	27.9	62.6	125.8	31.0	41.0	20.0
July	10.4	8.8	14.2	20.0	11.0	8.0
August	16.1	18.4	15.1	15.0	13.0	6.0
September	20.0	9.8	14.3	26.0	28.0	35.0
October	12.8	12.5	10.5	27.0	28.0	41.0
Average for 5 months, May-September	19.8	27.0	38.9	30.0	29.0	26.0
Average for 6 months, May-October	18.6	27.9	34.2	29.0	29.0	29.0
Average for 6 months, June-October	17.4	22.4	36.0	24.0	24.0	22.0

TABLE XVI.

Flow in Cubic Feet per Second per Square Mile, 1894.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Genesee	4.43	1.10	0.14	0.22	0.93	0.44	7.26	......
Hudson	1.94	1.76	0.81	0.63	0.47	0.94	6.55	......
Merrimac	1.55	1.40	0.50	0.37	0.40	0.50	4.72	......
Connecticut	1.26	1.00	0.44	0.27	0.31	0.53	3.81	......
Average	2.29	1.31	0.49	0.37	0.53	0.60	5.58	0.93

Inches of Rainfall Collected, Dry Year, 1894.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	0.910	0.450	0.380	0.410	0.460	0.660	3.27	......
Sudbury	1.500	0.720	0.290	0.370	0.260	0.670	3.81	......
Mystic	1.310	0.910	0.490	0.380	0.360	0.580	4.03	......
Average	1.240	0.693	0.390	0.390	0.360	0.640	3.70	......
Cubic feet per second	1.075	0.621	0.338	0.338	0.322	0.555	......	......

TABLE XVII.

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September and October, 1888.

	May.	June.	July.	August.	September.	October.	Summary.	Average.
Cochituate	2.05	0.47	0.410	0.82	2.00	2.23	7.980	......
Sudbury	2.52	0.66	0.180	0.59	1.78	3.09	8.820	......
Mystic	2.49	0.76	0.340	0.47	1.17	2.37	7.600	......
Perkiomen	0.80	0.34	0.220	1.32	3.29	1.09	7.060	......
Neshaminy	0.45	0.20	0.135	0.56	2.35	0.91	4.600	......
Tohickon	0.45	0.14	0.050	1.54	4.91	1.34	8.430	......
Average	1.46	0.43	0.220	0.88	2.60	1.84	7.415	1.236

Comparison of Eastern Streams. Flow in Cubic Feet per Second per Square Mile, Six Months—May, June, July, August, September and October, 1888 (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.	Merrimac.
May	2.05	2.52	2.49	0.80	0.45	0.450	5.10
June	0.47	0.66	0.76	0.34	0.20	0.140	1.40
July	0.41	0.18	0.34	0.22	0.13	0.050	0.53
August	0.82	0.59	0.47	1.32	0.56	1.540	0.57
September	2.00	1.78	1.17	3.29	2.35	4.910	1.69
October	2.23	3.09	2.37	1.09	0.91	1.340	2.95
Average, 5 months, May-September	1.15	1.14	1.04	1.19	0.74	1.420	1.86
Average, 6 months, May-October	1.33	1.47	1.27	1.18	0.76	1.405	2.04
Average, 5 months, June-October	1.19	1.26	1.02	1.25	0.83	1.590	1.43

TABLE XVIII.

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1888.
Per Cent. Collected.

	May.	June.	July.	August.	September.	October.	Average.
Cochituate	51.2	25.8	28.1	14.9	26.2	51.9	33.0
Sudbury	60.3	28.7	14.9	10.9	23.2	71.4	34.9
Mystic	56.5	38.1	17.5	8.8	15.3	55.3	31.9
Perkiomen	29.0	24.0	9.0	19.0	50.0	37.0	28.0
Neshaminy	18.0	9.0	4.0	11.0	38.0	28.0	18.0
Tohickon	17.0	9.0	2.0	22.0	66.0	38.0	26.0
Average	38.7	22.4	12.6	12.9	36.4	46.9	28.6

Comparison of Rainfall Collected in Eastern Streams, Six Months—May, June, July, August, September and October, 1888.
Per Cent. Collected (*Concluded*).

	Cochituate.	Sudbury.	Mystic.	Perkiomen.	Neshaminy.	Tohickon.
May	51.2	60.3	56.5	29.0	18.0	17.0
June	25.8	28.7	38.1	24.0	9.0	9.0
July	28.1	14.9	17.5	9.0	4.0	2.0
August	14.9	10.9	8.8	19.0	11.0	22.0
September	26.2	23.2	15.3	50.0	38.0	66.0
October	51.9	71.4	55.3	37.0	28.0	38.0
Average, 5 months, May-September	29.2	27.6	27.2	26.0	16.0	23.0
Average, 5 months, June-October	29.4	29.8	27.0	27.8	18.0	27.4
Average, 6 months, May-October	33.0	34.9	31.9	28.0	18.0	26.0

TABLE XIX.

Inches of Rainfall Collected, 1888.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Cochituate	2.37	0.530	0.470	0.940	2.31	2.57	9.19	......
Sudbury	2.91	0.730	0.210	0.680	1.99	3.57	10.09	......
Mystic	2.88	0.840	0.390	0.540	1.31	2.74	8.70	......
Average	2.72	0.700	0.360	0.720	1.87	2.96	9.32	......
Equivalent run-off	2.25	0.627	0.312	0.624	1.68	2.56	......	......

Flow in Cubic Feet per Second per Square Mile.

	May.	June.	July.	August.	September.	October.	Summary. Six months.	Average.
Merrimac	5.10	1.40	0.53	0.57	1.69	2.95	12.24	......
Blackstone (Uxbridge)	3.09	1.92	1.25	1.89	1.84	2.54	12.53	......
Charles River (Watertown)	3.23	1.62	0.55	1.86	1.65	3.24	11.15	......
Mother Brook (East Dedham)	1.78	0.83	0.36	0.38	0.77	1.81	5.93	......
Nashua River	2.30	1.32	1.28	1.33	2.33	4.82	13.38	......
Average	3.16	1.41	0.79	1.00	1.65	3.07	11.05	1.84

TABLE XX.

COMPARISON OF FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE OF EASTERN STREAMS IN WET AND DRY YEARS.

Dry Years.

Average flow of streams, five months, May to September, dry seasons.. 0.567
This would be a safe development of a stream.

Average flow of streams, dry years.................................... 1.290

Average flow of streams, five months, May to September, wet seasons.. 1.435

Average flow of streams, wet years.................................... 2.095

Note uniformity of flow of streams per square mile, irrespective of area of watershed. Also that five months' flow in wet seasons is at greater rate than yearly flow in dry years.

An average of the dry seasons' flow = 0.567; an average of the wet seasons' flow = 1.435; equal to 1, would represent the maximum safe development of a stream for power and manufacturing purposes, with an expectation of shutting down for two or three months in the dry season and installing auxiliary steam power.

TABLE XXI.

Month by per cent. of collection.	Month and number of days.	Average rainfall 1818-1897.	Average per cent. of collection.	Depth in inches of collection.	Equivalent run-off in cu. ft. per sec. per sq. mile.	
1	Aug. 30	4.35	21.3	0.9265	0.855	
2	July 31	3.68	21.8	0.8022	0.695	
3	Sept. 30	3.52	28.3	0.9960	0.895	0.808 average flow for 3 driest months.
4	Oct. 31	3.90	29.3	1.1430	0.990	
5	Nov. 30	4.30	36.5	1.5690	1.410	0.965 average flow for 5 driest months.
6	June 30	3.22	44.8	1.4420	1.290	1.019 average flow for 6 driest months.
7	Dec. 31	3.89	60.7	2.3710	2.060	
8	May 31	3.80	65.8	2.5000	2.170	
9	Jan. 31	3.95	76.3	3.0140	2.610	
10	Mar. 31	4.30	78.8	3.3880	2.940	
11	Feb. 28	3.80	132.2	5.0240	4.820	
12	April 30	3.98	145.0	5.7700	5.180	0.216 average flow per year.

Thus corroborating that one cubic foot per second per square mile is the maximum safe development of a New England stream for manufacturing purposes.

TABLE XXII.

GREATEST AND LEAST FLOW OF STREAMS.

RIVER.	PLACE.	Drainage area, sq. miles.	Extremes of Flow. Maximum cubic ft. per sec.	Extremes of Flow. Minimum cubic ft. per sec.	Maximum cubic ft. per sec. per sq. mile.	Minimum cubic ft. per sq. mile.	MEAN.	AUTHORITY AND REMARKS.
	NEW ENGLAND							
Merrimac	Lawrence	4,599.00	96,000	1,400.000	20.87	0.310	2.19	Lakes and artificial reservoirs. Wooded.
Concord	Lowell	361.00	4,449	59.840	12.32	0.170	1.39	C. Herschel. Stream sluggish and swampy. Few woods. Hilly and rolling. Some reservoirs.
Sudbury	Framingham	78.00	3,228	2.800	41.38	0.036	1.67	A. Fteley. Hilly and swampy. 1/6 to 1/8 wooded.
Connecticut	Hartford	10,234.00	207,443	5,219.000	20.27	0.510	1.86	T. G. Ellis. Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.
Cochituate	. . . .	1.90	. . .	. . .	. . .	.020	1.49	
Housatonic	. . . .	790.00	. . .	130.000	. . .	0.165	. . .	H. Loomis. Report, N. Y. Committee Public Works, 1879.
	NEW YORK.							
Croton	. . . .	338.82	25,367	50.800	74.87	0.150	1.65	J. J. R. Croes and G. W. Howell.
Croton (west branch)	. . . .	20.37	1,109	0.407	54.44	0.020	. . .	J. J. R. Croes. Very broken and undulatory.
	NEW JERSEY.							
Ramapo	Pompton	159.50	10,540	22.500	66.10	0.140	1.73	Minimum, October, 1892.
Pequannock	Pompton	84.00	4,460	. . .	48.90	. . .	. . .	
Pequannock	Macopin Int'ke	62.60	. . .	8.000	. . .	0.130	. . .	Clemens Herschel. October, 1875.
Rockaway	Dover	52.20	2,250	. . .	43.00	. . .	. . .	
Passaic	Paterson	796.90	19,105	150.000	24.20	0.190	2.58	L. B. Ward. September, 1883. This flow is occasionally not exceeded for more than two weeks.
Hackensack	New Milford	114.80	. . .	21.700	. . .	0.190	. . .	C. B. Brush.
Raritan	Bound Brook	879.00	52,000	180.000	59.30	0.200	1.72	Minimum by Ashbel Welch.
Raritan	Bound Brook	879.00	. . .	122.000	. . .	0.140	. . .	October 13th-19th, 1892. C. C. V.
Delaware	Stockton	6,790.00	254,643	1,179.000	37.50	0.170	. . .	Minimum, September, 1881.

TABLE XXII (*Concluded*).

Greatest and Least Flow of Streams.

River.	Place.	Drainage area, sq. miles.	Extremes of Flow. Maximum cubic ft. per sec.	Extremes of Flow. Minimum cubic ft. per sec.	Maximum cubic ft. per sec. per sq. mile	Minimum cubic ft. per sq. mile.	Mean.	Authority and Remarks.
	New Jersey.							
Musconetcong	Finesville	155.80	1,960	. . .	12.80	0.3900	1.14	
Paulinskill	Hainesburg	174.80	4,126	29.00	23.00	0.1700	1.69	Least in 1890.
Pequest	Townsbury	83.40	800	14.00	9.60	0.1700	. . .	Minimum from run of mill.
Great Egg Harbor	May's Landing	215.80	4,756	59.00	22.00	0.2700	. . .	
	Pennsylvania.							
Tohickon	Pt. Pleasant	102.20	5,546	0.21	54.30	0.0010	1.97	Annual reports of Chief Engineer of Philadelphia Water Department.
Neshaminy	Forks	139.30	5,767	1.26	41.40	0.0090	1.60	
Perkiomen	Frederick	152.00	5,305	7.56	34.90	0.0500	1.58	
Schuylkill	Philadelphia	1,800.00	. . .	307. to 378.00	. . .	0.17 to 0.2100	. . .	E. F. Smith and H. P. M. Kirkinbine. Hilly and rolling. No lakes. Some reservoirs.
Ohio	Pittsburg	19,000.00	. . .	2,271.00	6.17	0.1140	2.12	J. H. Harlow. Hilly and mountainous. No lakes. Wooded.
	Southern.							
Potomac	Dam No. 5.	4,640.00	92,772	363.00	22.15	0.0783	. . .	Quoted by W. R. Hutton. Narrow valleys. Steep slopes. Wooded. No lakes.
Potomac	Great Falls	11,476.00	175,000	1,063.00	15.25	0.0930	1.85	W. R. Hutton. Country more open. No lakes.
Kanawha	Charleston Pool	8,900.00	120,000	1,100.00	13.49	0.1230	. . .	Gill, Scott and Hutton. Mountainous. Steep. No lakes. Wooded.
	Western.							
East Carson	. . . .	41.40	. . .	. . .	10.26	0.7000	1.78	
West Carson	. . . .	7.00	. . .	. . .	18.34	0.5000	2.38	
Rio Grande	Del Norte, Cal.	1400.00	. . .	. . .	4.24	0.1400	0.80	

The average annual rainfall in Colorado is about 15 inches. This refers, of course, to the average of the whole State, valleys as well as mountain watersheds and table-lands.

It is a well-known fact in general that the amount of rain increases with the elevation above the sea level, up to a maximum plane, above which a decrease takes place, and empirical formulæ have been deduced for determining such proportions. The elevation at which the maximum rainfall is precipitated is, according to the observed law of decrease in temperatures, at that point at which the prevailing winds are cooled to just below their dew point.

Tables covering this subject are given in Report of the Geological Survey, No. 140, pages 328-329, etc., reference being made to the report of Prof. G. E. Curtis, Washington, 1884, Pamphlet XVI, Signal Service Notes.

Mr. Fellows, of the United States Hydrographic Office, stationed at Denver, Col., gave me as his opinion that the average rainfall on the San Miguel and Dolores watersheds was 18 inches. I have, however, assumed that the average precipitation upon the higher mountain sides and foothills, composing the larger part of the Beaver and Naturita watersheds, was 26 inches, for the following reasons, in addition to the statements above:

	Inches.
At Telluride, which has an elevation of 8756 feet, the average rainfall for fourteen years is	28.17
At Rico, elevation 8758 feet, average rainfall for twenty-eight years is	29.58
At Pikes Peak, elevation 14,134 feet, rainfall	28.65
At Summit, elevation 11,300 feet, average rainfall	29.00
At Fort Lewis, elevation 8500 feet, average rainfall	17.19
At Fort Garland, elevation 7937 feet, average rainfall	12.74
At Saguache, elevation 7740 feet, average rainfall	42.60
Grand average	26.85

At Ruby, which has an elevation of 10,000 feet, the average rainfall for—

	Inches.
1898	17.00
1899	44.97
1900	17.86
1901	29.12

An average of 27.26 inches for these four years. These four years, however, represent about 10 per cent. above the normal precipitation throughout Colorado. Therefore, deducting 10 per cent., the average rainfall at Ruby for the four years on the normal basis would be 24.53 inches.

I also append hereto the monthly rainfall for 1901, month by

month, at Telluride, which is in San Miguel County, and for 1900 and 1901, at Ruby, which is in Ouray County, and which is the nearest next available high elevation station, substituting an average amount for the two months omitted in the report:

	Rainfall at Ruby. Elevation 10,000 ft. Inches. 1900.	Inches. 1901.	Rainfall at Telluride. Elevation 8756 ft. Inches. 1901.
January	1.73	4.12	1.30
February	1.25	4.06	1.36
March	1.43	5.41	1.98
April	3.10	..	2.27
May	0.10	3.55	1.55
June	0.43	1.00	1.56
July	0.20	0.08	0.82
August	1.60	1.47	3.77
September	2.00	0.42	0.15
October	2.95	1.81	0.77
November	..	1.60	1.25
December	1.17	2.60	2.28
	15.86	26.12	19.06
Average Nov.	2.00	April 3.00	..
	17.86	29.12	19.06

And also a table giving the rainfall at Telluride, which is the only station from which reports have been made from June, 1901, to May, 1902, inclusive, substituting February and March of 1901 for the corresponding two months of 1902, for which months no returns were made:

RAINFALL AT TELLURIDE FROM JUNE, 1901, TO MAY, 1902.

June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.
1.56	.82	3.77	.15	.77	1.25	2.28	1.05	1.36	1.98	.54	2.83

The average for the composite year so applied is 15.3 inches, which is about 54 per cent. of the average Telluride rainfall. Therefore, the amount of water present and available this year in the Beaver and Naturita Creeks may be safely taken as being at least 50 per cent. below what might otherwise have been expected.

I give below two tables, one of the normal and monthly precipitation at Breckenridge, Summit County, and one at Rico, Dolores County, Col.:

BRECKENRIDGE, SUMMIT COUNTY—ELEVATION 9524 FEET.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	1.92	3.88	3.60	3.33	2.61	0.94	2.79	2.02	1.20	1.47	3.00	3.10	29.86
1895	3.29	2.31	2.37	1.88	4.39	1.81	2.43	3.62	1.11	1.95	1.76	2.67	55.59
1896	1.88	1.89	4.83	0.60	1.47	0.30	3.10	2.29	2.25	0.82	3.87	0.73	24.03
1897	2.90	1.99	3.53	4.00	1.54	1.53	1.30	2.27	1.16	1.02	0.60	2.25	24.49
1898	0.29	0.59	1.16	1.53	0.46	1.14	2.19	1.59	0.28	1.53	4.09	1.34	16.29

RICO, DOLORES COUNTY—ELEVATION 8737 FEET.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	2.78	4.25	3.34	1.21	2.09	0.68	2.58	2.27	2.55	1.08	1.03	2.58	26.44
1895	7.20	3.03	1.81	0.33	1.76	1.58	2.97	3.60	1.33	0.20	. .	2.75	. . .
1896	2.40	1.40	2.10	1.20	0.35	0.59	4.13	2.32	4.46	2.20	2.40	1.70	25.25
1897	3.26	5.60	6.40	1.66	4.15	0.98	2.41	. .	5.80	2.82	1.60	2.02	. . .
1898	3.10	1.35	3.80	2.62	3.82	1.60	3.10	4.13	0.88	0.15	0.85	. .	. . .

RUN-OFF.

We now come to the next most important question, which is that of run-off, or the proportion of rainfall which finally finds its way to the stream. Mr. Fellows, of the State Engineer's Office, advises me that the run-off from 1895 to 1899, from April to November, inclusive, for the section under consideration, amounted to but 7.12 inches, which would be 39.6 per cent. of the rainfall, which he also gave me.

The report of the United States Geological Survey for 1898 gives the run-off of the San Miguel River for the year 1897 as a total of 10.09 inches, equal to an average of .74 cubic foot per second per square mile, a copy of which table is given on following page:

DRAINAGE AREA OF SAN MIGUEL RIVER.

327 square miles.
Run-off for 1897.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Depth in inches	.21	.19	.21	2.20	2.20	2.64	1.33	.64	.73	.64	.32	.26
*Sec. ft. per sq. mile	.18	.18	.18	0.65	1.91	2.37	1.15	.56	.66	.56	.29	.23

Total run-off in inches, 10.09. Average run-off, .74 second feet per square mile.

I also give below a table of the discharge of the San Miguel River from the same point of observation, Seymour, otherwise known as the mouth of Fall Creek, Col., which gives the discharge in cubic feet per second, and also the run-off in inches and in cubic feet per second per square mile for the last six months of 1899:

ESTIMATED DISCHARGE OF SAN MIGUEL RIVER AT SEYMOUR, COL.

Drainage Area, 327 square miles.

1895.	Discharge in second ft. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Run-off. Depth in inches.	Second ft. per sq. mi.
July	675	219	347	21,336	1.22	1.06
August	312	145	230	14,142	0.81	0.70
September	168	61	100	5,950	0.35	0.31
October	101	42	64	3,935	0.23	0.20
November	180	..	30	1,785	0.11	0.10
December	..	..	10	615	0.03	0.03

*Sec. ft. = cubic feet per second.

1898.	Discharge in second ft. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Run-off. Depth in inches.	Second ft. per sq. mi.
April, 11-30...	..	..	272	16,185	0.92	0.83
May	545	196	296	18,200	1.04	0.90
June	1335	571	813	48,377	2.79	2.49
July	760	109	380	23,365	1.34	1.16
August	183	109	133	8,178	0.47	0.41
September	121	66	89	5,296	0.30	0.27
October	66	30	50	3,074	0.17	0.15
November	66	22	40	2,380	0.13	0.12
1899.						
April	299	25	134	7,974	0.41	0.46
May	934	126	414	25,456	1.27	1.46
June	995	249	538	32,013	1.65	1.84
July	387	176	238	14,634	0.73	0.84
August	387	105	195	11,990	0.60	0.69
September	138	64	101	6,002	0.31	0.35

As the year 1895 was rather a dry year, and the year 1897 was a notoriously wet year, these measurements may fairly represent the maximum and mean run-off measurements of the San Miguel, although having a much larger area (327 square miles) than either the Beaver Creek, with 88 square miles, or the Naturita Creek, with 53 square miles, and as all of these streams have a common source of supply from the San Miguel and Dolores Mountains, the percentages obtained from one and the run-off in cubic feet per second per square mile may be fairly applicable to the other.

To demonstrate the mean and maximum discharge that may be obtained in this section I append a table, giving the mean discharge in cubic feet per second for May, June and July of the years 1895, 1896, 1897, 1898 and 1899:

Mean Discharge of San Miguel River in Cubic Feet per Second.

	May.	June.	July.
1895	....	556	341
1896	770	349	157
1897	627	774	375
1898	296	813	380
1899	416	538	238
	2109	3030	1491
	527	606	298
	606		
	298		
	1431		

Average = 477 ÷ 327 square miles = 1.458 cubic feet per second per square mile

which shows that June gives the highest average discharge, and also that the average discharge for the three months' period for five years is 1.458 cubic feet per second per square mile.

It also shows that the three months' discharge of 1897 was 35 per cent. greater than the average three months' discharge of 1896, 1898 and 1899, proving conclusively the relation that the year 1897 bears to the other years. The maximum discharge, which was found on June 16, 1897, is 3.05 cubic feet per second per square mile, and may be safely taken as the maximum discharge per square mile of any stream in this immediate vicinity.

DISCUSSION.

Mr. Charles T. Main.—I have not had sufficient time to prepare any extended discussion of Mr. Webber's paper, but would like to say a few words on one point only which is discussed in the paper, viz., the economical development of a water power.

Mr. Webber has stated that about 1 cubic foot per second per square mile is the maximum commercial development, or the flow which corresponds to about the sixth month of an average year.

In a very large number of plants which I have examined, fully 90 per cent. have been developed to use all the water from six to seven months of an average year, and a large part of these plants have been installed without any particular engineering skill, the size being based upon the horse sense, one might say, of the owners. This is at variance with the very frequent testimony which we hear that the proper size of the development is one which will use all the water for at least nine months of an average year, and sometimes the statement is made that the economical limit is eleven months, with water wasting for only one month.

For the average power used for manufacturing purposes, say ten hours a day, a six to seven months' development is more nearly correct than eleven months, but no general statement can be made to cover all cases. It is simply a question of economics, which requires solving for each particular case.

The factors which enter into the problem are, on one side, the cost of the water-power development and the fixed charges on the same, if nothing is paid for the water, and, on the other side, the saving which can be affected by the use of such plant.

The cost of the dam will be a constant for any size development of wheels, all other conditions being the same. The headgates, canal, racks, feeders, wheels, wheel pits and tailraces must be increased in size and cost for the purpose of using a larger amount of water than the flow in the average month or sixth month of an

average year, and the fixed charges for such increase in cost represent the annual cost of the corresponding increase in water power.

The saving due to such increase in water power is represented by the saving in coal only on the supplementary steam plant, necessarily run with such a varying water power, plus the cost of attendance on steam plant, if it can be shut down entirely during the months of maximum power on the wheels. As the water power is increased in size to use water for a greater number of months, the cost of such increase for each additional month makes a saving for a less number of months, and there comes a time when the saving on steam power is less than the fixed charges on the additional cost of water-power plant. Where these two items balance depends upon the following conditions:

(1) Cost of water-power plant for each increment of power.

(2) Saving affected by the decreased use of steam power, which would be very much more if the power is used twenty-four hours than if used for ten hours, and much more if by such an increase in the water-power plant it is possible to shut off all steam power.

An example will suffice to make this clear. Supposing the cost for each additional horse power of water-power plant required to use all the water for a longer period was $60 a horse power. The fixed charges on this, including interest, will be not less than 8 per cent., or $4.80 per year. The cost of coal and attendance on a steam plant, of say 500 horse power, with coal at $4 a ton, is about $13 a year per horse power, or $1.08 per month. $4.80 ÷ $1.08 = 4.44 months. In other words it would not pay to develop such a power to use all the water for more than about seven and one-half months.

If the engine or boilers cannot be shut down at all, a less saving could be made and the power could be economically developed for a less period than seven months.

The various conditions and lengths of time required to have the saving equal the fixed charges are shown on the following plate. This diagram is figured on coal at $4 per ton. Similar ones could be made for any other prices.

To use the diagram, supposing the water-power plant cost $50 per horse power and the size of steam plant is 200 horse power, on the ordinates find $50, cost of water-power plant. Run along horizontally until this line intersects the vertical line of 200 horse power of steam plant, and these two lines will be found to intersect about on the curve marked three months.

If the water-power plant cost $70 and the steam plant were

350 horse power, the time is five months during which water should waste.

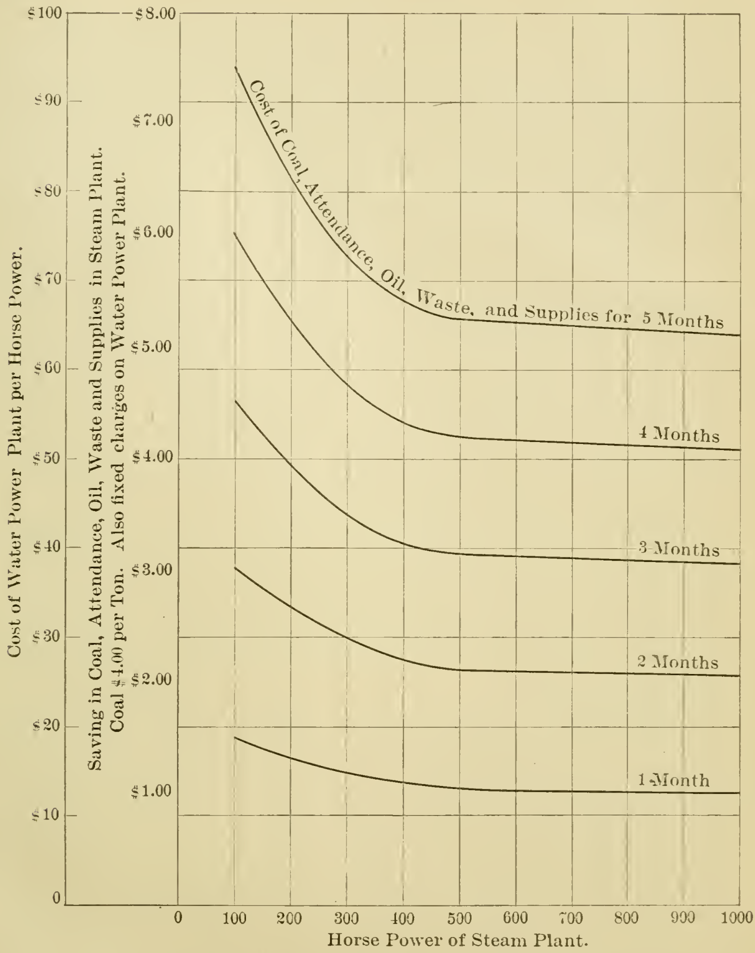


Diagram Showing Number of Months when water should be allowed to Waste with different sizes of Steam Plants and different Costs of Water Power.

Mr. Richard A. Hale.—In regard to the development of power on a stream very much depends on circumstances, but, in general, the sixth or seventh month would be the maximum amount to which a stream should be developed, and beyond that point much would depend on the local conditions and use of power required, depending on the amount of steam power used in connection with the plant.

In regard to the yield of streams the tables presented by Mr.

Webber are very interesting. The minimum flow on the Merrimac, he states, is .31 cubic foot per second per square mile. In the year 1883, which was an exceedingly dry year, the minimum yield for one week was .27 cubic foot per second per square mile, and in the year 1900 it was about the same amount. The minimum weekly yield, in general, during an average year, will seldom fall below .3 cubic foot per second per square mile. This yield is for twenty-four hours flow for a week of seven days. Owing to the water being used principally during the five and a half days of each week and stored Saturday afternoon and Sunday, the average flow for one week shows the yield of the river nearer the truth than for one day, when the water may be held back for storage or a large amount sent down from the accumulation of storage in ponds in the upper reaches of the river. The drainage area of the Merrimac River is 4450 square miles, and the measurements of the flow of the river are computed at Lawrence from daily observations. The results are published in the yearly report of the United States Geological Survey in the Hydrographic Department. The accuracy of the measurements is probably within 3 per cent. of the truth. The error may reach 5 per cent., and perhaps somewhat more with unusual conditions of ice in the river and broken flashboards.

In comparison with smaller drainage areas it is interesting to observe how much lower yield is obtained during the dry months from the smaller area.

In 1880 to 1883 the writer had occasion to measure the flow of the Shawsheen River at Andover, Mass. Daily measurements were made during this period, but the results have not been published, owing to anticipated lawsuits at that time. I may state, however, that the lowest yield during the driest week was .10 cubic foot per second per square mile, from a drainage area of 70 square miles. During the same period, the yield from the Merrimac River watershed was .27 cubic foot per second per square mile. On the Spicket River, at Lawrence, the writer has been making some measurements during the last two years, and during the early part of October of the present year the yield for a period of two weeks was somewhat less than .10 cubic foot per second per square mile from a drainage area of 68 square miles.

It is an interesting fact to notice on a large stream and large watershed that the amounts from small streams, as tributaries, are extremely low, and in some cases almost nothing. The yield of the large river reaches a certain point and does not fall below that point, being supplied from the subterranean reservoirs at a lower level than the smaller streams.

The yield of the Shawsheen River in an ordinary year during the driest week is .16 cubic foot per second per square mile, while the yield of the Merrimac River during a similar period is .32 cubic foot per second per square mile.

In connection with the investigations of the flow of the Charles River by the writer for the Charles River Dam Commission, some interesting facts were ascertained. During the dry period of the year 1900, at the Boston Manufacturing Company, at Waltham, there was a period of three weeks when the water wheels were not run on account of lack of water, and the leakage through the wheel gates could not supply enough water for the use of the bleachery below without taking off flashboards from the Boston Manufacturing Company's dam. This yield indicated from .10 to .15 cubic foot per second per square mile. This drainage area was about 163 square miles. There was no doubt large evaporation at this period from the ponds above the various dams.

It is gratifying to know that the State Board of Health is keeping a record of the flow of the Charles River at Watertown, and important information in regard to the flow will be obtained.

PROF. DWIGHT PORTER.—Fair consideration of the run-off data which have thus far been obtained warns the engineer against expecting too high a degree of accuracy in estimates of flow based upon drainage area, rainfall and the observed discharge of certain standard streams, such as the Sudbury. And yet time has confirmed the writer's opinion that this method, if intelligently used, will often give results entitled to great confidence.

He has often felt, with Mr. Webber, that the Sudbury has been made to carry too heavy a load of responsibility in serving as a standard for so many streams as have been referred to it, but this seems excusable, since perhaps no other stream has been so closely or for so long a time observed. If there were others that had been studied with equal skill and thoroughness, they would no doubt receive equal weight, and we should be in better position than we are for making estimates in new cases.

Our dearth of information will be overcome in time, as data accumulate, and especially as other engineers follow Mr. Webber's example and put the facts in print where we all may benefit by them. Our members may not all know that the United States Geological Survey is attempting to gather and publish such data on a very extensive scale. It has in operation a large number of permanent gauging stations in various parts of the country, and in its annual reports for the past few years and in the bulletins issued under the title of Water Supply and Irrigation Papers will be found the results

of the gaugings, as well as many discharge records furnished by water-power and mill companies.

In considering estimates in damage cases it is apparent that engineers differ, not only in regard to the actual cubic feet per second to credit to streams in question for different parts of the year, but also as to how far, if at all, above the minimum the flow shall be classed as having practical value for power. Some are disposed to include the average flow for the year in their valuation, or even a part of what might be classed as freshet flow, while others admit but scant value in water power, and are inclined to credit a stream with little more than its minimum flow. Between these extremes there appears to the writer to be a proper line, not necessarily determined by average June flow or with reference to the five driest months, but depending upon the circumstances of each case, marking the limit beyond which it is simply uneconomical to instal turbines which must be largely duplicated in engines and will be for much of the time either idle or running inefficiently.

So far as concerns the scientific computation of the varying yield of a watershed for different proportions of the year, the difficulties encountered are of several kinds. The more simple data involved are the drainage area, amount of rainfall and run-off for the standard basin and the drainage area and rainfall for the stream under estimate. Of these the drainage area can probably be determined with the most accuracy, but unless there are maps at least as good as those of the Geological Survey, errors of several per cent. seem likely. The average rainfall over such a watershed as the Sudbury is perhaps known very closely, but that can scarcely be said of the Connecticut, or the Merrimac, or the Kennebec, or of any other stream draining much unsettled country, since in the higher and less-settled regions there are but few rainfall stations, and these are likely to be conducted by unskilled and inconstant observers, whose records display many gaps. The actual run-off from the Sudbury basin may be known within a very few per cent. of the truth, but can we put equal confidence in figures for the Connecticut for past years, the Kennebec or even the Merrimac in high stages? Even were these data unimpeachable, there still remains the difficult problem of referring to the standard basin the one in question and recognizing the points in which they are alike in geology, topography and climate and the points in which they differ, and of not only recognizing these, but assigning numerical values to them. Under these circumstances are we not forced to admit a considerable probable error in the result?

There seem to be two saving factors. Errors of a few per

cent. in such computations would seldom occasion much concern; and, further, the estimates which are made will probably never be fully checked. If one estimate the average flow of a stream at 400 cubic feet per second when he should have called it 300, who is going to find it out, since careful and continuous observations for a series of years would be needed to establish the truth? It is unfortunate that this is so, since greater certainty of a check would lead to greater care in estimating.

In studying the records of our northern streams with reference to their percentage of yield there are certain opportunities for error, which the writer thinks are liable to be overlooked. It is natural to study these records by calendar years, beginning January 1st and ending December 31st. But if, on January 1, 1903, there were, on a New Hampshire or Maine river basin, 20 or 30 inches of snow which had fallen in the previous calendar year, and on December 31, 1903, little or no snow, the stream would have received in the meantime a considerable amount of water which had no connection with the current precipitation of the year. The same thing would be true if the storage reservoirs were drawn lower by the end of the year than they stood at its beginning, and yet we seldom have the means of correcting the gross run-off from watersheds for the sources of error above mentioned. Still, again, in comparisons of different basins it is important to regard their different percentages of water surface, or we may be drawn into serious error in our conclusions.

To take a somewhat extreme example, data in the writer's possession indicate that the Winnepesaukee Lake basin supplied at the outlet dam, in 1885, the equivalent of about 31 per cent. of the rainfall for that year on that basin, including the lake surface; but if we correct the figures for the difference in lake level between the beginning and end of the year, the percentage of yield changes from 31 to 40. If we next allow for the fact that the lake probably received a little more during the year from rain falling upon its own surface than it lost by evaporation, we get the amount which presumably flowed into the lake from that portion of the drainage basin exterior to its own surface, and for that area the percentage run-off appears to be 49 per cent. But this exterior portion of the basin contains considerable lake and pond surface, probably amounting to as much as 8 per cent., and if we now apply, as before, a correction for the probable difference between rainfall and evaporation on this 8 per cent., we find our percentage of yield to rainfall for the remaining land surface to be as high as 53 per cent. But even this may not be right, for there is no means of knowing how the snow

depth over the basin compared at the beginning and end of the year, or how the storage in the lakes and ponds comprising the 8 per cent. of water surface compared at the beginning and end of the year. Similar difficulties confront one in a detailed study of many basins. The errors which have been indicated tend to disappear, as we neglect single calendar years and embrace periods of several years in our computations, for in this averaging process the effect of irregularities of snow and lake storage becomes relatively less and less.

It seems doubtful whether much of positive value comes from studying percentage relations between yield and rainfall for individual months, inasmuch as there seems to be no close connection between the two in so short a time. Thus, by Table II, in May, 1873, the flow of the Connecticut appears to have been 217 per cent. of the rainfall for that month. Obviously, the flow of the stream was derived only in small part from the May rainfall, and would have continued in large volume even had there not been a drop of rain in May. Even in so large a period as a year, the stream flow must be considerably dependent upon the condition of ground water established in the previous year, or perhaps further back; nevertheless, the general relation between the run-off and rainfall is the more accurately seen as the period considered increases.

To the writer the study of run-off statistics is very confusing and tedious, if confined to figures, and he believes that much may be gained in the drawing of conclusions by plotting such data whenever possible, and so presenting them graphically.

Mr. Freeman C. Coffin.—Such papers as this of Mr. Webber's, giving records of stream flow, are very valuable to the hydraulic engineer.

I would like to emphasize what he says about the necessity of taking into consideration the condition of the watershed in connection with its area and the amount of rainfall. The Sudbury River has been spoken of, and we recognize the great value of the long series of measurements of its flow that have been taken. Their value lies in the length of time and the accuracy with which they have been made. They can be used, with the exercise of judgment, in watersheds on which the conditions differ. I made measurements on a river in the southeastern part of this State for four years. These show a larger flow per square mile during the summer seasons than the Sudbury, largely, I believe, on account of the local character of the ground, which is mainly level and largely composed of sand or gravel, which acts, to a certain extent, as a storage reservoir, and this question of underground storage is just as im-

portant in consideration of the distribution of the run-off and flow of streams as the visible storage of lakes or ponds. It does not effect the total or average run-off. We find that in the same section of the country this is very much the same for all streams.

The distribution of the run-off is greatly affected by the underground storage, being larger in dry seasons and smaller in wet seasons, when the storage is considerable.

In regard to the effect of the rainfall the amount of the flow or yield depends upon the rainfall, but the percentage varies greatly with the different seasons, and Professor Porter's statement that the yield of any month cannot be determined by the rainfall of that month alone is very true, and, in considering the rainfall, it is just as important to take that of the preceding month, and even the month before that, into consideration as the rainfall of the month itself. For instance, in a case where it was desirable to deduce the amount of the flow from the rainfall of a certain watershed in this State, and where actual measurements were not available at that time, I applied the Sudbury River run-off to the watershed in question, using months of like rainfall on the Sudbury to the month under consideration, selecting those in which the rainfall of the preceding month was also similar to that of those preceding the month in question, and made an estimate, which turned out (after the actual run-off, as determined by the engineers on the other side by weir measurements, was known) to be within 2 or 3 per cent. of the amount, which was a much closer estimate than I had hoped to make. The closeness of the result may have been a mere coincidence, but it shows that a fair approximation can be obtained by the use of the Sudbury records, when careful consideration is given to the varying conditions.

In making estimates of water power it is quite customary to use averages, and in some relations they are useful, and in others, very misleading. The average run-off in October and November is low, while the average in January is fairly high. In a case with which I was recently connected it was estimated that the filling of a large storage reservoir caused the mill owners below much damage, on account of the retention of the water required to fill it. The reservoir was filled during the months of October, November and December, 1895, and January, 1896, and upon looking up the data, using the Sudbury River run-off, I found that the flow of October, November and December was much greater than the average, and thus while the reservoir was filling, the flow in the main river was far in excess of the wheel capacity of the mills, and therefore the diversion of the water required to fill the reservoir caused no loss

of power. In January alone was there any shortage; so that, based upon averages, there would be a loss to the mill owners. When the particular year was considered, there was no actual loss.

Regarding the figures of the flow of the Manhan River, referred to by Mr. Webber, which were taken by Mr. Tighe, City Engineer of Holyoke, the yield is given of every day in the year, which makes these tables of very great value, as they give, not only the average daily flow for the months, but the maximum and minimum daily flow.

There is one set of conditions from which very little data of flow have been collected, those pertaining to the streams of northeasterly New England and the Canadian provinces, which are icebound in winter. I know of very few instances of reported flow of these rivers, and these records cover but a short period of time. It will be of great value to the profession when the records of such streams are more complete. It is probable that the flow of January, February and March would be very different from that in Massachusetts or the Sudbury flow during the same months. In that part of the country the rain during these months is in the form of snow; many of the small brooks are frozen completely and the winter flow is small compared with that in places with higher temperature.

Mr. Main.—Mr. Coffin spoke of the desirability of getting some records of streams which are icebound in the winter.

The St. Croix River, at Taylor's Falls, was gauged by the U. S. Engineers during December of 1881 and eleven months of 1882. Below are given the results of these measurements, and opposite the gaugings is given the rainfall as recorded by the U. S. Weather Bureau in St. Paul for the corresponding months.

About a year and a half ago daily gaugings were begun and have since been continued for parties who are interested. These records will soon be of value.

The area of the watershed at Taylor's Falls is about 5950 square miles.

Rainfall and Run-off.

Month.	Rainfall in inches.	Run-off in cubic feet per second.
1881.		
November	1.36	..
December	0.53	3,500
1882.		
January	0.67	2,700
February	2.35	3,400
March	3.25	4,100
April	1.61	16,100
May	2.44	15,700
June	2.68	9,700

Month. 1882.	Rainfall in inches.	Run-off in cubic feet per second.
July	2.84	9,900
August	2.45	5,200
September	0.27	3,800
October	1.99	6,300
November	1.61	4,800
Average		7,100

The recent gaugings are being plotted together with the temperature of the atmosphere on the same sheet. It is interesting to see how the rise of temperature is followed soon by a rise of flow.

MR. LEWIS M. HASTINGS.—While it is self-evident that the amount of rainfall on a given catchment area must have an important influence on the run-off from that area, yet it seems to be pretty generally conceded that no general relation can be stated by formula or otherwise, which will accurately give this relation as applicable to all catchment areas.

The elements or factors determining this relation are too various and too little understood to enable the engineer to more than approximate it. The character of the surface, whether pervious or impervious, and the area of water surfaces must exert more or less influence on the amount of the run-off in percentage of rainfall, while the steepness of the slopes, the amount of forestation and the size and shape of the catchment area affect its distribution.

In comparing areas of very different sizes a considerable difference in the flow during the dry season was noted, areas of about 1 square mile yielding about 75 per cent. of the yield per square mile from larger areas.

This same general result is noted by Mr. C. C. Vermewle, C.E., in his report on the water supply and water power of New Jersey, 1894. He gives the minimum flow of seven streams, each having a catchment area of over 2000 square miles, as .182 cubic foot per second per square mile of catchment area; on twelve streams, having between 200 and 2000 square miles area, the average minimum flow was .161 cubic foot per second per square mile, and on twelve streams, having less than 200 square miles area, an average minimum flow of .094 cubic foot per second per square mile,—showing a constant diminution in the minimum flow with the reduction in catchment area.

With regard to the use of a stream for power, if the June flow be taken as the maximum flow to which it will be wise to develop a water power and the Sudbury River records be used as a basis, but about .742 cubic foot per second per square mile will be found.

I have always understood that it was the *May* flow rather than June, and Mr. Francis so testified in a case in which I was interested. In other cases I have found the actual development by mill owners to be about that given by the *May* flow. By observing the average run-off of the Sudbury River it will be found that May, December and January each give substantially the same run-off. The three months, February, March and April, give much larger flows and the remaining six, much smaller flows. It would seem reasonable, then, that a power should be developed to take as nearly as possible the flows of May, December and January, wasting the surplus in the three months of flood flow and making up with steam the deficiency during the six dry months.

Mr. T. Howard Barnes.—I am reminded, in this discussion, of the investigation of the capacity of Spot Pond as a source of water supply for Boston, made between June and November, 1845, by Messrs. John B. Jervis and Walter R. Johnson, for the city of Boston. At that date there were no run-off records of like localities such as we have now. There were records of rainfall taken at Boston and at Waltham for periods of twenty-seven and twenty years, respectively; also some evaporation observations. The run-off, therefore, had to be determined, and the direct and accurate work done by the engineers is an interesting and instructive example of obtaining results from apparently meager data.

In applying the records of the Sudbury run-off up to 1894 the safe capacity of the Spot Pond source was estimated at 1,640,000 gallons per day, based upon utilizing the storage of the pond to a depth of 15 feet—837,000,000 gallons. The estimate of Jervis and Johnson was 1,450,000 gallons per day, utilizing the storage to a depth of 5 feet—384,000,000 gallons. It should also be noted that the average rainfall over the Sudbury area, 1875-1902, is 46.38 inches, while that of the Boston records in 1845 was 39.31 inches.

The following extracts are taken from the report alluded to, and are presented here mainly because of their historic interest:

Period.	Average daily flow, gallons.	Aggregate gallons.
1. June 26 to July 12	2,455,300	39,285,000
2. July 12 to July 19	7,711,848	48,521,500
3. July 19 to July 29	417,506	4,261,901
4. July 29 to August 7	4,674,200	42,067,800
5. August 7 to August 17	154,448	1,533,668
6. August 17 to August 30	2,583,500	34,195,185
7. August 30 to September 22	894,121	19,670,668
8. September 22 to October 2	493,640	4,766,590
9. October 2 to November 1	937,688	28,130,635
Total		222,432,947

Or at a mean rate, for 128 days, of 1,737,760 gallons per day equal 231,710 cubic feet, and a total bulk of 29,657,700 cubic feet.

This drainage has reduced the level of the pond about 44.5 inches, and left it so nearly exhausted that the daily flow was, on November 1st, but 329,832 gallons.

Since the first of August, when our survey of the area of the pond was made at water level, there have been drawn from the outlet 17,381,859 cubic feet, reducing the surface 23.04 inches.

The quantity of rain which has been gauged during the months of August, September and October has been 10.17 inches, and of evaporation, 15.732 inches; showing that, at this period of the year, the evaporation from the water surface exceeds the rain which fell upon it by $5.562 \div 10.17 = 54.69$ per cent.

During the last five periods of observation in which we have been enabled to ascertain the amount of drainage derived from the watershed, it appears to have given the following proportions, viz:

In the 5th period	—10 days	....	19.5 per cent.
" " 6th "	13 "	....	15.1 " "
" " 7th "	23 "	....	14.7 " "
" " 8th "	9 "	....	17.5 " "
" " 9th "	30 "	....	17.5 " "

If each of these percentages be multiplied by the number of days in its period and the sum of the products be divided by the whole number of days, we obtain an average of 16.6 per cent., which proves that the slopes themselves, at this season of the year, evaporate or otherwise dispose of 83.4 per cent. of the water which falls upon them. These results prove the ratio between the evaporation from the surface of the pond and from that of the slopes, consisting mainly of a soil covered with vegetation, to have been—in August, September and October last—$.8340 \div 1.5469 = 53.9$ per cent.

The depth of water which the pond actually received from its watershed during the above period of eighty-five days was .709 foot, or 8.41 inches, which, added to the depth of rain given above, makes the total amount received 18.58 inches; from which, deducting the evaporation, we have $18.58 - 15.73 = 2.85$ inches for the height which the pond would have risen by all the rains had no water been drawn from the outlet.

Dr. Hale has found that, at Boston, the months of August, September and October together afford, on an average of twenty-two years, 9.62 inches of rain. This year they gave, at Spot Pond, 10.17 inches, or .55 inch = 5.7 per cent. above the average, which proves that the season has not been one of unusual dryness. This is confirmed by what has been found at Long Pond (Lake Chochituate), where, in the same period, 10.4 inches of rain have been gauged, showing a difference of only .23 inch from the Spot Pond observations, but .78 inch above Dr. Hale's general average.

The evaporation gauged on Spot Pond is 6.32 inches above the general average of 9.41 inches, which, in a period of three years and with an evaporating vessel 9 inches deep, Dr. Hale obtained in Boston. The difference amounts to 67.2 per cent.

This may probably be, in great part, attributed to the different depths of the vessels employed. In our apparatus the water was always kept at a height about 2 inches only below the top of the cylinder. By being immersed in the pond, the cylinder and its contents always maintained nearly the same temperature as the latter. Hence it had at night as well as in the daytime the same evaporative power, for a given area, as the pond. More than one-third of the evaporation generally occurred during the night.

The pond being now empty, we have next to consider the means by which it will probably be filled.

Dr. Hale found, in twenty-two years, an average depth of rain falling in November, December, January and February amounting to 12.93 inches. He also found for the same four months an evaporation of 3.3 inches. If we suppose that the surface of the Spot Pond district during the ensuing four months receives the same quantity of rain and undergoes the same evaporation, the depth of $12.93 - 3.3 = 9.63$ inches $= .802$ foot would remain; and if the average area of the pond be taken at 200 acres, the direct supply from rain will be $43{,}560 \times 200 \times .802 = 6{,}987{,}024$ cubic feet.

Admitting also that the ratio of evaporation on the land to that on the water shall be the same in winter as it has been in summer and autumn (53.9 per cent.), the watershed will send into the pond, from its whole surface, a depth of $12.93 - (53.9 \times 3.3) = 11.15$ inches, or 86.2 per cent. of all the water which it receives; and this, on an area of 898 acres, will give $43{,}560 \times 898 \times .929 = 36{,}339{,}580$ cubic feet, which, with what is derived directly from the rains by the pond itself, makes 43,326,604 cubic feet supplied in 120 days. From this, deducting what has been drawn out in 120 days of our observations, which is equal to $231{,}710 \times 120 = 27{,}805{,}200$, we have left 15,521,404 cubic feet to be drawn within the following four months, leaving the pond about the height at which it stood on the 3d of July last. This affords for the average daily drainage of the two periods of 120 days in each, or 240 days in all, 180,527 cubic feet, or 1,393,950 gallons.

If we admit that the winter rains at Spot Pond will exceed those at Boston as much as did those of the autumn, viz, 5.7 per cent., the above quantity will be increased by 77,175 gallons daily, and the average daily supply will then be 1,471,125 gallons = 181,556 cubic feet. This seems the most favorable view which can be taken of the winter supply of water to the pond.

In March, April, May and June the average rain in Boston is 12.85 inches, and the evaporation, 13.26 inches; from which, it appears certain, that the pond cannot be expected to receive *directly*

in rain any accumulation or addition to its height in those four months. The only question is as to the proportion, which will be furnished indirectly by the surrounding lands. We have no direct observations which will determine this proportion. But as the months of May and June are, in temperature and moisture, not very unlike August and September, it may reasonably be inferred that the land will, in those two months, give the average evaporation of the periods which we observed, and, therefore, afford about 17 per cent. of drainage; and if we give to March and April the same proportion as the four months which precede them, viz., 86.2 per cent., the average of the four months will be 50.41 per cent. Hence a fall of 12.85 inches of rain will give $43{,}560 \times 898 \times .5395 = 21{,}103{,}600$ cubic feet of water to the pond, and affords a daily drainage for the 122 days in those months of 172,980 cubic feet, or 1,297,350 gallons.

In order to afford a daily supply of 1,471,125 gallons, the slopes must furnish over their whole area a depth of $(181{,}556 \times 122) \div (43{,}500 \times 898) = .5662$ foot, or 53 per cent. of the rain falling in these months.

The experiments and computations already given, showing the quantity of water actually derived from the watershed, do not favor the supposition that any very extraordinary proportion will be available for drainage over this district, since the highest result obtained—that for the fifth period of observation—was only 19.5 per cent.

In view of all the facts that have been ascertained and the observations that have been made, it may be assumed that a ratio of not more than six-tenths of the total fall of rain may be relied on from the district drained.

The gauge kept by Dr. Hale, at Boston, is about 8 miles from the center of the district, and that kept by Dr. Hobbs, at Waltham, is between 5 and 6 miles. The proximity is such that they may be considered in the general result as a good guide for this object. From 1818 to 1844 inclusive—twenty-seven years—the minimum fall of rain at Boston was 29.98 inches in one year. There are nine years in the series that fall below 36 inches for one year, and three years that fall below 33 inches in each year. The average for the series is 39.31 inches. At Waltham, in a series of twenty years, commencing with 1825, the minimum fall was 34.09 inches in one year, and three years in the series fell below 36 inches in each year.

In deciding on sources to supply a city with water it would not be proper to take the average of a series of years. A town will need more water in a dry season than in a wet season, and, consequently, that source only, which affords a sufficient supply at its minimum capacity, should be adopted. In a season of unusual drought no benefit or consolation for a short supply of water could be obtained, from the fact that in other years large quantities had

run to waste. If the Waltham gauge (being nearest in location, and, perhaps, most applicable) be taken, then 34 inches is the minimum; and this is strictly the proper datum for such a computation. But, as only three years out of twenty fell below 36 inches, it may be regarded as reasonably safe to assume 36 inches as the annual fall, and more especially as this will not, on the ratio of 6-10, materially exceed the lowest gauge of the commissioners in 1837 and 1838. On this basis the annual amount will be $.6 \times 3 \times 39{,}204{,}000 =$ 70,567,200 cubic feet, equal to 1,446,138 gallons per day.

After a careful examination of all data that have been obtained it appears that Spot Pond may be relied upon to supply about 1,500,000 gallons per day. It may, and probably will, in some years fall a little below, but it will generally afford this quantity. The area of Spot Pond, as before stated, contains, when full, 296 acres; at a level, 5 feet below the high-water line, it contains 196 acres. Between these levels it therefore appears there are 100 acres which are covered, when the pond is full, with not exceeding 5 feet depth of water and a large portion from 1 to 3 feet in depth. This bears a proportion to the whole area of the pond of 34 to 100, or a fraction over one-third of the pond is shoal water, no part exceeding 5 feet in depth. There is, doubtless, some objection to this amount of shoal water not sufficient in depth to prevent the free growth of marsh grass and other aquatic vegetation.

Mr. Webber.—I would like to say that it was to bring out just such discussion as this that I ventured to perpetrate this paper, and because I believe there is a vast amount of very reliable data on other streams which have never been published, and which, if it were published, would be of great benefit to all of us.

For some reason or other it seems to me that on the different engineering problems that I encounter, the first difficulty I meet with is that available data do not seem to apply to the particular problems in question. I have to deal with a very small watershed and cannot find much data on small watersheds; or, with a centrifugal pump and find nobody has ever made any tests on centrifugal pumps, and so on. In the case for which I originally prepared these data I could not find anything but the records of the Sudbury, Mystic and Cochituate Rivers. Everything related to the Sudbury River. I was soon convinced that the Sudbury River was not a universal tape measure of every stream in the world, and soon found very reliable data for the Tohickon, Neshaminy and Perkiomen Rivers, which have been kept, as far as I can find out, practically ever since the introduction of the Philadelphia Waterworks. They have been very carefully kept, probably as accurately as the Sudbury River records, but were never published.

Now all these gentlemen who have spoken have some data ex-

tending over four or five years. Most of the data have never been published. That is the reason why I bring this up,—to get you to publish some of your results. There is a lot that is still tied up, owing to pending litigation, but I believe a larger proportion is not tied up and could just as well be published as not, and it is to draw out that publication that I am now making these few remarks.

I want also to corroborate what one of the other gentlemen said about the great value of plotting the rainfall and the run-off. I think records of rainfall and run-off should be plotted on the same chart, so that you can see the results at a glance, whereas you plot it on different scales. We then see on the same chart day by day and month by month the flow of the stream and the rainfall at the same time. I know in this particular case I plotted the stream in question for the run-off and rainfall daily for four years. The United States Geological Survey records are particularly valuable, because they do that very thing, besides the figures, which are harder to get a mental conception of; in almost every case there is a diagram in black and white. Picture writing appeals to a man, and he can see it much easier and better.

If we can only have published the data all these engineers have in pigeonholes, we will be far ahead, and we will not be using one tape measure to measure enormous varieties of work.

Mr. Arthur T. Safford (by letter).—I have read Mr. Webber's paper with much interest, and am glad to see this additional information to our increasing knowledge of the flow of streams.

While there is probably no question as to the accuracy of our stream measurements, I am of opinion that we can never get, in practice, the yields of streams figured upon average conditions elsewhere, unless we have storage far in excess of anything which we usually obtain. In this discussion I will confine myself to streams like the Merrimac and Concord Rivers.

This discussion was prepared very hurriedly, and I am sorry that I was not able to present more new information. It has been a part of my duty for a number of years to divide the water flowing in the Merrimac and Concord Rivers among the different mill owners; and I have been impressed with the apparent discrepancies between the average flow of the stream and the flow available for water-power purposes. Records are obtained from water powers above Lowell, the conditions of use and storage in mill ponds are studied and every effort is made to reduce waste and to make the daily use as large as possible. In spite of this a large quantity of water runs to waste during even the dry seasons,—after sudden storms,—and we never get average conditions such as the figures of

yield would seem to warrant. The extremes of flow are very great and a larger portion wasted than engineers have been in the habit of estimating. It is my purpose to give a few figures in support of the theory that unless we can store a large part of the yield and keep it in reserve we cannot count on averages.

Table XXI of Mr. Webber's paper gives for the Merrimac and Concord Rivers the following minimum and mean flows on a twenty-four-hour basis:

	Drainage area sq. miles.	Minimum flow cu. ft. per sec.	Minimum flow cu. ft. per sec. per sq. mile.	Mean cu. ft. per sec. per sq. mile.
Merrimac, at Lawrence..	4599	14.00	.310	2.19
Concord, at Lowell.......	361	59.84	.170	1.39

The minimum flow given for the Merrimac and Concord looks small, but they are not as low as the actual figures for 1900.

Mr. R. A. Hale, of Lawrence, Mass., sent me some figures of the Merrimac, at Lawrence, corrected for the Nashua, Sudbury and Lake Cochituate, in which, for the week ending September 16, 1900, the net twenty-four-hour yield of the Merrimac was but 1264 or .284 cubic foot per second per square mile. Mr. Hale's drainage area is different from Mr. Webber's, but not materially. I find that our own records at Lowell for that week show that, including the Concord and making the same corrections, the twenty-four-hour yield was 1253 cubic feet per second, without including Beaver Brook, which may have contributed just the difference between Mr. Hale's and our figures.

During this same week, the Concord River, with its 301.3 square miles of watershed, excluding the Sudbury, averaged just 16 cubic feet per second or .053 cubic foot per second per square mile. All power on the river at Lowell was shut off, and the Lowell Bleachery, which requires about 10 cubic feet per second for bleaching and other manufacturing purposes, was compelled to wait a day until the water was wasted through the gates from the mill pond at North Billerica, which had not filled up over Sunday. This is an extreme case on the Concord River, and yet it may be an ordinary occurrence, for a few weeks, on a stream where there is absolutely no storage excepting in mill ponds, which may be drawn down at will, so that the natural flow of the stream, while filling up, will be cut off.

On the Concord River, at Lowell, there are seven water wheels, drawing about 405 cubic feet per second from the Wamesit Canal, or 1.34 cubic feet per second per square mile of watershed, excluding the Sudbury. The 75.2 square miles of the Sudbury River furnishes an amount which varies from almost nothing in dry weather

FLOW OF CONCORD RIVER FROM 1888 TO 1901, INCLUSIVE, MEASURED JUST BELOW LAWRENCE STREET BRIDGE, LOWELL. THE QUANTITIES GIVEN ARE FOR MONTHS OF TWENTY-FOUR WORKING DAYS OF TEN AND ONE-HALF HOURS EACH, ARRANGED IN ORDER OF DRYNESS. FLOW COMPILED FROM RECORDS OF WAMESIT CANAL; QUANTITIES ARE IN CUBIC FEET PER SECOND.

Months in order of dryness.	1888.	1889.	1890.	1891.	1892.	1893.	1894	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Average 1888 to 1901 inclusive.	Cubic feet per second per square mile.
1	164	294	228	173	164	147	84	108	127	184	253	155	69	179	163	.54
2	237	410	278	210	203	164	136	176	152	225	274	160	132	236	214	.71
3	303	571	285	226	216	175	189	193	171	256	323	169	161	256	250	.83
4	382	629	425	264	317	233	243	239	297	260	438	213	210	285	317	1.05
5	523	705	490	287	318	274	279	274	347	424	635	239	271	293	383	1.27
6	638	755	640	308	384	294	285	288	357	440	750	279	293	410	437	1.45
7	944	835	688	320	396	309	288	299	392	475	895	288	430	430	499	1.66
8	1,525	915	888	388	475	399	329	437	490	509	959	318	570	500	622	2.06
9	2,505	1,065	995	649	570	530	455	562	550	510	1,070	694	750	850	840	2.23
10	2,508	1,685	1,372	2,285	660	870	600	845	680	668	1,250	1,250	830	1,310	1,201	3.19
11	2,519	1,884	2,053	2,285	943	1,340	861	1,086	1,100	997	1,490	1,720	1,235	1,690	1,514	4.02
12	2,552	1,909	2,075	2,295	1,425	1,980	1,681	1,750	2,110	1,377	2,110	2,305	2,505	2,325	2,028	5.39

Note how much the average for each month is increased by a few wet years like 1889, 1890 and 1898.

NOTE.—Area of watershed above Lawrence Street Bridge, Lowell, Mass , is 376.5 square miles. (From Massachusetts State Board of Health Report, 1890, page 411.) Since 1879, the city of Boston has used the Sudbury River, which takes a part of the watershed of the Concord River above the Lawrence Street Bridge as a water supply. The watershed of the Sudbury River, at the lowest point of taking, is 75.2 square miles.

to about its normal yield for the few wettest months. These wheels run for 10.5 hours a day, and during dry weather there is comparatively little waste at night. The lawful quantity owned by the mills is 288 cubic feet per second, or .96 cubic foot per second per square mile from 301.3 square miles, the balance of 117 being surplus. When there is less than 288 cubic feet per second running during the working day, each mill draws its proportional part of the actual flow. As showing the actual conditions under which water can be drawn, I give the quantities drawn by the wheels during the years 1888 to 1901, made up in order of dryness, in months of twenty-four days, twelve months being equal to 288 days, or the working year, less holidays. I have added, in the last column, the corresponding yield per square mile on the basis of 301.3 square miles for the eight driest months and 376.5 square miles for the remaining four, this being approximately correct.

It is evident from the figures in this table that, even with the storage in the mill pond at North Billerica and Lowell and almost no night running, it is not possible to get the permanent quantity of 288 cubic feet per second for the four driest months, using all the years and not the average, and the six driest months during the so-called drier years. The column called average, 1888 to 1901 inclusive, however, would seem to indicate that in an average year, so-called, there would be only three months when less than 288 cubic feet per second could be depended upon, and it would be fair to infer from these same averages that it would pay to put in wheels to take at least 500 cubic feet per second to save coal in six months. If the ponds and swamps are full in the early part of the year and the rainfall comes gradually and is evenly distributed, we can depend upon average conditions, but this rarely happens; and without large storage, either in ponds on the watershed or in mill ponds, it is not possible under ordinary conditions to prevent some of the water getting by without its being used.

In order to bring out clearly the danger of using average conditions let us compare the Sudbury average yield with the measured conditions on the Concord River, of which the Sudbury contributes 75.2 square miles of its 376.5 square miles. On the basis of twenty-seven years' yield of the Sudbury River (1875-1901) the average yield in gallons per day per square mile is 1,081,000 for the year, and 441,000 for the driest six months. Arranging in order of dryness on the 10.5-hour basis and neglecting the Sunday waste, we should expect from the 301.3 square miles, outside the Sudbury for the eight driest months and for the full 376.5 square miles for the remaining four months, the following yields:

Months in order of dryness.	*Average Sudbury yield by years. 1875-1901 gallons per day.	Corresponding yield c. f. p. s. 10.5 hours.	Same reduced to 301.3 sq. miles c. f. p. s.	Average flow at Lawrence St. Bridge, Lowell, c. f. p. s.	Per cent. of monthly quantities on Sudbury basis measured at Lowell.
1	194,000	.687	207.0	163	78.7
2	238,000	.842	253.7	214	84.4
3	301,000	1.065	320.9	250	77.9
4	480,000	1.698	511.6	317	62.0
5	518,000	1.832	552.0	383	69.4
6	924,000	3.268	984.6	437	44.4
7	1,105,000	3.908	1177.5	499	42.4
8	1,163,000	4.113	1239.2	622	50.2
9	1,205,000	4.262	†1604.6	840	52.3
10	1,889,000	6.681	†2515.4	1201	47.7
11	2,075,000	7.339	†2763.1	1514	54.8
12	2,923,000	10.338	†3892.2	2028	52.1
Average for year	1,081,000	3.823	1335.2	705.7	52.9

It is seen that on a 10.5-hour basis only 80 per cent. of the flow on the Sudbury average basis is available at Lowell for the three driest months, and that during most of the year it is not much more than 50 per cent. The Sudbury average monthly yield varies from 194,000 in July or 17.9 per cent. of the average to 2,923,000 in March, or 270.4 per cent. Individual dry months go down to — 35,000 (August, 1899), or less than nothing, and up to 4,453,000 (March, 1891), or 411.9 per cent. of the average. The weekly fluctuations are still greater and the weekly flows are controlled, to a large extent, by storms of a day. All these affect the actual flow and make it difficult to depend upon definite quantities of water.

In using the Sudbury or any other basis for water-power purposes it is necessary, I think, to know, in addition to the size of the watershed and the amount of storage, at least the average slope of the watershed, the capacity of every mill pond, the area of swamps, both on the watershed and in the bed of the stream, and the customary running at each water power, with a special study of the average height of the water there as shown by marks. Finally, with these facts known, we should apply, not the Sudbury average monthly records for a long term of years, but the actual records each month from year to year. Where large storage exists, it will be necessary to take the rainfall collected on the land surface, which increases as the ponds are drawn down, and evaporation from the corresponding water surface and actually try certain assumed yields up to the limits of the storage. This method will throw into the

*P. 240 Metropolitan Water and Sewerage Board, First Annual Report.
†376.5 sq. miles.

waste column a large part of the yield of wet years, when the storage is not sufficient to store the yield. This is ably treated in an article by Frederic P. Stearns, C.E., in the Report of the Massachusetts State Board of Health for 1890, and, in this connection, particular attention is called to the diagram opposite page 350.

I think the Sudbury basis, intelligently handled, the best one we have at present in New England; but the Sudbury average records sometimes produce results which do not exist in fact when applied to other watersheds, and give a mistaken idea of a steady flow, which is kept up during the summer and fall months by the "average rainfall collected." This year (1903) I think of as about an average year, as far as total rainfall is concerned. The rainfall for May, 1903, was .818 inches, or, with one exception, the month was the driest in seventy-five years; while June, 1903, was 9.106 inches, or the wettest for the same length of time. The careful man who began to handle his reservoirs on the basis of a dry year, this year, found a large amount of waste inevitable after the June rains.

I only use this as an illustration, but it brings out the fact that it is very much easier to look back upon records and see what could have been done than know what to count on looking ahead. There is a line between over-conservatism and risk, and good judgment will save us from either error; but we cannot fail to use every possible shred of information which can be obtained, and should not be content to accept forever the Sudbury average basis, as customarily used in court cases, as the whole truth and a panacea for all difficulties.

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THE PHYSICAL STRUCTURE OF METALS AND ALLOYS.

BY J. J. KESSLER, JR., MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Abstract of paper read before the Club, April 15, 1903.*]

THE subject which is to be considered under the title of this paper is usually treated as "The Microstructure of Metals and Alloys." This is a little misleading, as it implies that this is one of the particular kinds of physical structure which is being involved, whereas, as a matter of fact, the whole anatomy or architecture of the metal or alloy is being considered, and the microscope is concerned only in that it is an indispensable instrument of research on account of the size of most of the structural elements.

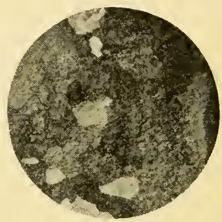
An alloy is defined by Roberts Austin as any mixture of metals, or of metals and metalloids, which, on cooling, does not separate into layers. This is a broad definition, and yet any narrower definition must exclude many substances, the most important of which is cast iron, which cannot be defined as a solid solution nor as a chemical compound, but which is a true alloy in the sense of the definition. In fact, brass and bronze are not more truly alloys than is cast iron.

The first structural elements to be considered are those present in pure metals. It is well to call to mind here that chemically pure metals are not to be found as engineering materials. They have all, to a greater or lesser extent, associated with them impurities which were originally present in the ore or which have been acquired during the process of reduction from the ore.

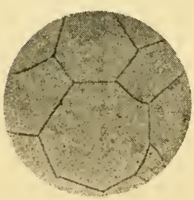
*Manuscript received December 15, 1903.—Secretary, Ass'n of Eng. Socs.

The figures shown (Fig. 1) are one and all of common character; they all indicate crystalline arrangement. Whether it be the metals lead or tin, or, at the other extreme of physical properties, antimony or bismuth, not shown, it may be seen that each metal is an aggregate of crystalline grains bounded by definite surfaces, and that no metal, however pure, may be said to be homogeneous, but that each is an aggregate of homogeneous grains or crystalline units, homogeneous in themselves, but possessing limited volume and bounded by surfaces, the forces pertaining to which are very different in character from the forces within the grains themselves.

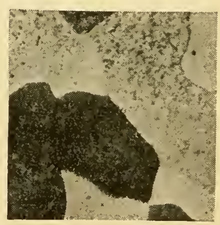
Tin.



Lead.



Iron.



Platinum.

Fig. 1. Illustrating the Crystalline Structure of Pure Metals.

The distinctive difference between metals, therefore, is not one of crystalline character. We cannot explain the physical difference between lead and antimony, for instance, by stating that one is crystalline and the other not. All metals are truly crystalline, and the difference between them must be found in differences in the properties of their crystalline grains and in the forces existing between the crystalline grains.

An interesting point which comes up in this connection is the effect of stress on these pure metals. When a metal is yielding to stress, and the deformation has not reached the elastic limit, no change in the structure of the metal can be recognized under the microscope. When, however, the elastic limit has been reached

and plastic yielding of the metal begins, the change is indicated in a very characteristic way.

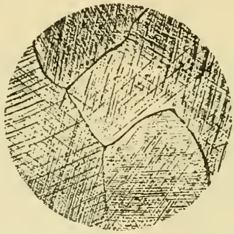


FIG. 2. PURE LEAD STRESSED UNTIL PLASTIC YIELDING HAS OCCURRED.

Fig. 2 shows an appearance quite different from that of any structure which has been yet observed. Large crystalline grains are shown as before, but on the face of each grain will be seen a number of series of parallel lines running across the entire surface of each grain, but each series ending abruptly when the boundary of the grain has been reached. These series of parallel lines are not scratches on the surface of the metal, and they begin to appear only when the elastic limit of the metal has been reached by stressing.*

This appearance of parallel lines in the structure of a metal when the yield point of the metal has been reached by stressing is common to all metals which have been thus far examined. Closer examination of the surface of the metal reveals the fact that these lines represent the connecting surfaces between parallel planes, which are at slightly different levels.

An ideal cross-section of a metal so strained would be represented as shown in Fig. 3.

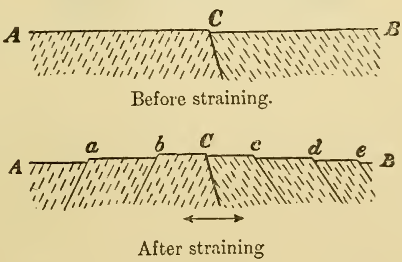


FIG. 3. IDEAL CROSS-SECTIONS OF PURE METAL BEFORE AND AFTER STRAINING.

Strain in a metal, therefore, is not a question of homogeneous shear, as in the case of a liquid, but takes place by the successive slipping, over one another, of the inter-crystalline grains. The most severely strained metal still retains its crystalline structure, the effect of the stress being to elongate the crystals in one direc-

*Ewing and Rosenhain, "Phil. Trans. Roy. Soc.," cxciii, p. 353.

tion, as in the case of rolled or hammered steel, and this is what gives the metal its fibrous qualities. The use of the word fibrous, in connection with a metal, is therefore correct, only in that it indicates either crystals elongated by stress, or impurities, present in the metal, which are elongated by stress. This is invariably the case in wrought iron, which is fibrous only when it contains elongated crystals of iron or other structural elements, or when it contains elongated portions of slag or other impurities.

Pure metals are not used in the arts, however, to the extent to which mixtures of metals are used.

Mixtures of metals, which on cooling do not separate into layers, may contain three different kinds of constituents:

(1) Homogeneous solid solutions.

(2) Distinct crystals of one substance distributed through another.

(3) Liquid solutions which on cooling have frozen into solid solutions; but which, at the instant of freezing, have separated into alternate layers of the different constituents.

These three different kinds of constituents are illustrated in the following figures. (Figs. 4, 5 and 6.)

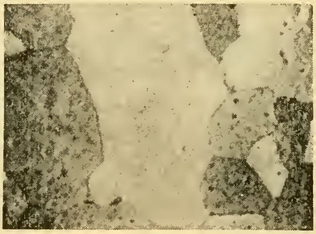


FIG. 4. SILICON IRON ALLOY (4 PER CENT. SILICON).

The first case is represented by the silicon iron alloy, which is seen to be made up simply of crystalline grains, the silicon being diffused through the mass of iron, the whole being a true solid solution of silicide of iron in solid iron, which cannot be separated from the iron by mechanical means, whose composition may vary uniformly with certain limits, and which is, therefore, a true solution.

The properties of such an alloy will be similar to those of the pure metal, and will depend on the properties of the individual grains and on the forces existing between the grains.

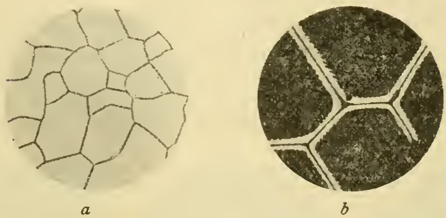
In the case of such an alloy it can be predicted that for any given change in the percentage of silicon present, no radical change in the properties of the alloy, over that of the pure metal, will take place; for instance, if the electrical conductivity of the metal be

represented by a certain figure, the addition of 0.01, 0.10 or even 1 per cent. of silicon will not materially affect this conductivity.

The second class of alloys may be represented by the micro-

a, Outside of casting ; *b*, inside of casting.

PIG IRON, SHOWING DISTRIBUTION OF GRAPHITE.



a, Pure copper ; *b*, copper containing 5 per cent. bismuth.

NOTE.—The light and dark areas of *b* should be reversed in order to be comparable with the light and dark areas of *a*.

FIG. 5. ALLOYS CONTAINING DISTINCT CHEMICAL CONSTITUENTS OF ONE SUBSTANCE DISTRIBUTED THROUGH ANOTHER.

photographs of pig iron or of bismuth copper alloy (Fig. 5). In this case, entirely distinct constituents are seen in different parts of the metal. If the first class of alloys mentioned be compared to a solution of salt in water, the second may be represented by the case of a solution of salt and water, which has been cooled to a point where solid salt has been separated from the solution. This represents by far the most common forms of alloys. In cooling, the homogeneous molten mass separates out different constituents, which remain diffused through the still molten mother liquor, which finally freezes, forming the solid alloy. The properties of such an alloy may be entirely different from those of the pure constituents.

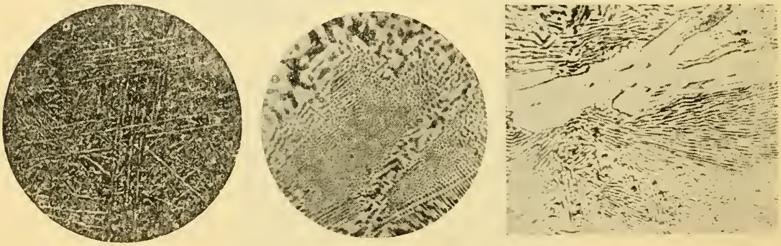
The bismuth copper alloy, shown in the micro-photograph, contains 0.5 per cent. of bismuth. This bismuth does not form a solid solution as in the case of the silicon iron alloy. In this case a small amount of bismuth unites with a large amount of copper to form a eutectic alloy (see next paragraph), and this alloy is forced out of the growing crystals of pure copper, until finally, in the solid alloy, it forms a shell of brittle bismuth copper eutectic

around each grain of copper, thus giving the characteristic brittleness and shortness to the metal. In the case of such alloys it can be predicted that, for any given change in the percentage of impurity present, a radical change in the properties of the alloy over that in the pure metal will take place.

For instance, the electrical conductivity of copper being represented by 100, the addition of 0.001 per cent. of arsenic reduces this to 99.5, or the addition of 0.010 per cent. reduces the conductivity to 95.3, the arsenic forming, with copper, an alloy similar to the bismuth copper alloy shown.

There is still another structural component of alloys, and, although seldom found as constituting the entire structure of any alloy, it forms a very important structural constituent of most alloys. This is called the eutectic alloy.

When a molten homogeneous solution of metals is allowed to cool, as has been stated, different constituents become insoluble as certain temperatures are reached. These separate out and become structural components of the finally solidified alloy.



Lead silver. Iron; phosphide of iron. Iron; carbide of iron.

NOTE.—The large white area in the right-hand photograph represents free segregated carbide of iron.

FIG. 6. CHARACTERISTIC STRUCTURES OF EUTECTIC ALLOYS.

Whether such action has or has not taken place, however, there comes a point where the remaining solution freezes as a whole. If the metals can form a solid solution, as is the case with the first class of alloys, this will be done. If the constituents are not mutually soluble to one another, a separation will take place at the instant of solidification, and the resulting alloy will be found to consist of alternate layers of the different separated constituents. A strong magnification is required to resolve this kind of structure. This alloy is always characterized by the fact of its having the lowest melting point of any of the whole series between two metals. It is, in fact, always a solidified mother liquor. The composition of the eutectic alloys of any two metals may be ascertained either by analyzing the alloy which shows the proper eutectic structure, or by studying the freezing point curves of different alloys composed

of the same metals, but of varying composition. Fig. 6 shows the eutectic alloys of several metals.

Every alloy, therefore, will consist of either one, two or all of the three different constituents named above, each combination of metals forming its own characteristic solid solutions, chemical combinations, eutectic alloys, etc., the size and arrangement of these structural units being a function of the temperature from which the alloy is cooled, the rate of cooling and the work done on the alloy, either while it is being cooled or after it has reached temperature equilibrium. It must always be remembered that simply heating a series of alloys with the same chemical composition, to the same temperature, does not necessarily imply that the alloys will be in the same structural condition; this will only be the case when the metals have been held at the required temperature long enough for complete equilibrium to take place through diffusion, etc.

Very important results have been obtained by studying the physical structure of alloys; two instances will be given where good has been accomplished in entirely different branches of metallurgy.

In the first instance it has been found that there is only one temperature from which cast steel, 0.29 per cent. carbon, may be annealed, in order to give the greatest tensile strength combined with the greatest ductility; this has been found to be the temperature which gives the smallest crystalline grains on annealing. The different results, obtained by annealing from different tempera-

Fig. 7. Illustrating the Effect of Annealing Temperature upon the Structure of Cast Steel.

tures, are shown in Fig. 7, both as affecting the sizes of the crystalline grains and as affecting ductility, as measured by the bending test and as shown by the figures of the test bars above the microphotographs, each one having been bent to the angle shown before breaking occurred.

The second field in which the microscope has proved to be of great assistance is in studying sheet electrical steel, 0.07 carbon,

with reference to the relations between its physical structure and its magnetic properties. It has been found that the lowest hysteresis is found in steel which contains the best developed crystalline

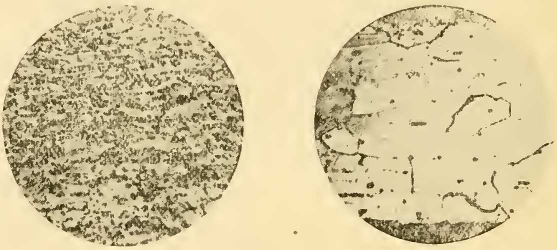


Fig. 8. Showing Improperly and Properly Annealed Transformer Sheet Steel.

grains, and these are developed only when the steel has been subjected to a definite heat treatment.

These are only two instances of a large number of cases in which the microscope has been found to be useful in studying the physical structure of metals and alloys, a feature which is becoming recognized as being of quite as much importance to the knowledge and control of these materials as is chemical composition.

PATENT LAWS. ARE THEY ANY LONGER NECESSARY TO PROGRESS IN MECHANIC ARTS?

By George W. Dickie, Past-President Technical Society of the Pacific Coast.

[Read before the Society, October 2, 1903.*]

The subject of this short paper is one that should interest the members of this Society, although the present presentation of it must necessarily be defective, owing to the press of other matters on the time and thought of the author.

Only one week ago the Secretary of this Society requested that I should prepare a paper for this meeting, and this subject was in my mind at the time; in fact, a patent attorney was waiting to consult me in regard to evidence required to defend a suit for alleged infringement of a patent, one of a class now so numerous, where the principal novelty is in the combination of words that describe the claims.

Patents appear to have had their origin in the ancient practice of giving to favorites monopolies or special privileges in connection with the making or vending of such things as they dealt in by the reigning prince in absolute or restricted monarchies. This evil practice worked great hardship on the less-favored body of purchasers and consumers, and trade was thereby greatly restricted. The British people forced from the unwilling James I a statute declaring void all these burdensome monopolies, with the distinct exception regarding letters patent and grants of privilege as follows: "Sole working or making of any manner of manufacture within the realm to the true and first inventor of such manufacture, which others, at the time of making such manufacture, should not use, so they be not contrary to law, nor mischievous to the state by raising of the price of commodities at home, or hurt of trade or generally inconvenient." These words form the foundation upon which has been built the whole structure of the law of letters patent.

The inventions for which patents are granted are either vendible articles, such as machinery or apparatus, or processes. A mechanical principle cannot be the subject of a patent unless its application to some useful end be shown. The principal classes of patents seem to be granted on:

First. New contrivances that produce new results.

Second. New contrivances that produce old results.

*Manuscript received December 1, 1903.—Secretary, Ass'n of Eng. Socs.

Third. New combinations of old and well-known parts, whether the combination relates to the operation or to the result.

Fourth. New methods of applying a well-known device.

The spirit of the patent law is that the benefit or improvement must be manifest and of importance with regard to claims for patents touching well-known objects and processes, and great skill is sometimes displayed in so wording a specification as to bring this requirement into prominence, the object of the law being that the rewards to come to the patentee will be a just recompense to him for his labor in the wide sense that though his labor may not in itself have amounted to much, though the change in process or application be small, still, if the general scope and utility of application or process, or whatever the patent may cover, be enlarged to the benefit of the public, the inventor (though in this case only an improver) is entitled to a just reward for his discovery, and this reward his patent gives him an opportunity to secure. In the case, which often happens, of a party making some discovery not already patented, but openly used by someone else, though not to his knowledge, no patent is allowable, but should the discovery have been previously made and be kept secret, then the party who first obtains a patent is the legal inventor, irrespective of priority of invention on the part of any second party. In Great Britain a patentee may be compelled by law to grant licenses to persons to work his patent should they be able to prove that the public is being defrauded of the use of the patent.

The whole reason for the existence of patents is the monopolizing by the inventor, for a limited period, of the benefits derived from an invention, on the supposition that there will result a lasting benefit to the public after the term of the patent has expired.

A very small percentage of the patents granted meet this condition, for, to do so, they must cover real inventions. The mechanical arts have reached such a stage of development that new combinations of mechanical devices, in the sense of invention, is hardly possible, and, in my opinion, a patent should be issued only where some new contrivance has been invented to produce a new result. I would not have any real inventor go unrewarded, but, in order to recompense the few inventors who have done work worthy of recognition by their fellow-men, it should not be necessary for the public generally, and the mechanical arts in particular, to carry the huge load of patent-protected devices of all sorts described in patent specifications, which, owing to cleverly worded claims, prevent a free application of the proper device to accomplish the end in view.

I have reached my present position on the patent question through experience in my daily task of continually seeking the best mechanical means to accomplish the end in view. In order to illustrate the kind of patent that stands in the way of progress, seeking to exact royalty on claims that should never have been allowed, I may cite a case where the holder of a patent is at present claiming damages from the company with which I am connected for alleged infringement of the claims on which he has been allowed a patent:

In 1898 the United States Navy Department issued specifications for three battleships. On page 37 of that specification there is the following requirement: "Lifting gear to be provided for all armored hatch covers which can be worked by hand power from above and from below. Such shutters and doors of armor as may be directed are to be fitted to be opened and closed by electric power, the electric power appliances to be worked without disconnecting the hand gear." And on page 49 there is the following requirement: "The principal sliding water-tight doors below the protective deck, as directed, to be operated on an approved system by power, each such door to be capable of being operated by hand or power from either side, and all to be capable of being closed simultaneously from a distance by power from two stations located as directed. The distance control must not incapacitate each door from operation on either side at the door by power."

A company had been making doors for such use under patents. These were at first hydraulic doors, but after some experience with them new patents were obtained for doors operated by air, and now this company has bought or otherwise secured patents for doors operated electrically. The claims under these patents are all very broad and cover the combination of a door, the bulkhead to which the door is secured and the mechanism for operating the door. Now, bulkheads are not new, doors secured to bulkheads are not new and mechanism to operate doors attached to bulkheads is not new. But to come back to our case: In October, 1898, the contract for one of these three battleships from whose specification I have quoted was awarded to the company with which I am connected, and, after the more important matters connected with the beginning of such a contract were attended to, I began to consider how I would meet the requirements of the specification as to doors and hatches to be operated by power.

Some time in December, 1898 (exact date unknown, for we never consider that what we do at any time may be required as evidence in a patent case), I talked this thing over with our

electrician and decided to operate these doors and hatches by electric motor, using the ordinary vertical sliding door frame and screw, simply taking the doors we had been making for years, applying a special motor to operate the screw and using the control devices that we had used for other purposes, it never occurring to us that any invention was required to meet the case.

We could not start the plans for these doors for some time, owing to press of other work. I find, however, that on February 13, 1899, I wrote the president of our company, who had sent me a proposed plan from the other company offering their hydraulic doors for use in this battleship, as follows: "The number of vertical sliding doors for the ship has not yet been determined, nor what number of them should be operated by any power system at a distance. Our intention is to devise an arrangement for operating them by electric power, and we will take it up as soon as we can possibly get at it. The prices given for these doors are altogether too great to make it advisable to think of using them." About this time I think that we must have begun to make plans for these doors, as the contemplated plan was signed and dated May, 1899. A sample door was made, and a sample portion of bulkhead to which the door was attached, the bulkhead being in the form of a tank to test the water-tightness of the door. This was set up in the shipyard some time about July, and the door was thoroughly tested and found to operate very satisfactorily. Here, again, I cannot fix dates, for it never occurred to me that I was inventing anything and that evidence would be needed to establish who the inventor was, there being nothing new about any of the devices used. When the door was found satisfactory, the plans were submitted in the usual manner and approved, and the work was started.

In November, 1899, I was in New York, attending the meetings of the Society of Naval Architects and Marine Engineers, and there learned that the naval constructor at the New York Navy Yard had been getting up an electrically-operated door to meet the requirements of the specifications from which I have quoted, and had a sample one set up at the yard. He invited me over to the yard to see his door and note in what way it differed from the one I had designed, so I went to see it and found that it also consisted of a combination of well-known devices, although differing from mine. He used a rack on the back of the door instead of a screw, the pinion gearing with the rack being carried on a shaft, which also carried a worm wheel, in which the worm on the motor shaft geared. This was not so simple as the motor

direct on the screw, as I had it, and has not proved so effective. We talked freely about the difference in the doors, each trying to show the other where his door had the advantage, but neither said anything about being an inventor.

About a month after this the naval constructor made application for a patent on his door, with broad claims covering the combination of a bulkhead, a sliding door and motor, with controlling devices for operating the door. This patent was granted in 1900, sold or assigned to the before-mentioned company, who have started suit against the company with which I am connected for a large amount of damages and injunction against using the door I got out to meet the requirements of a Government specification. It may be said that such a suit will not be successful, but it will cost the company several thousand dollars for its defense.

I have stated this case at length because it is the best illustration I have at present of the kind of patent business that should be stopped. In this case (and it is representative of ninety-nine cases out of every hundred) there is no invention required. The door is the same as has been used for many years. The wedges that force it on the face when it reaches the proper position are the same as have always been used for that purpose. The screw that works the door, either vertical or horizontal, is the same as has always been used. When operated by hand it could be operated either at the door or at a distance. By and by a specification requires it operated by power, and I decide to do it electrically. For this purpose I use a motor such as we had used for telemeter purposes, gear this motor properly to the screw that operates the door, use well-known devices for controlling the movements of the motor, both at the door and at a distance, and in doing this it never occurred to me that any invention was required to combine these various well-known devices. At the same time a Government officer, knowing what this specification required, also took a door, such as had been used for many years, with the wedges to force it on the face when it reached the proper position, discarded the screw that had so long been used to work it by hand, fitted a rack on the door, a pinion to work in the rack and a shaft with a worm wheel on the shaft—a motor with a worm on its shaft to work in the wheel and with well-known controlling devices at the door and at a distance. After his door was finished it occurred to him that he had invented something in connection with it, and he applied for a patent with claims covering the whole combination. The patent was granted and then sold or assigned to the company that brings suit to recover damages from others who had the door

in operation several months before any patent was applied for. Had I thought anything was being invented when designing this door, I could have applied for a patent several months before the other. Now an expensive defense must be made against the claim of the party holding this patent, although, if invention were necessary to the securing of a patent, this party could not have obtained one.

I do not wish to be understood as opposed to all patents. I believe in rewarding everyone who, by invention or skill, succeeds in making new combinations of well-known devices to accomplish results whereby the public will be ultimately benefited, and I would have such rewards liberal and sure; but patent claims cleverly worded to cover combinations of well-known devices—to accomplish well-known results obtained for business purposes—that are to prevent others from using the same combinations or mechanical equivalents I would abolish, and thereby stop 90 per cent. of the patent business, with decided advantage to the real inventor, who at present is lost amid the multitude of imitation inventors and patent sharps.

What I propose would hardly be received kindly by the general public. The general public's heart is quite soft in regard to such things. It is generally believed that the inventor is a mechanical genius who needs protection, pursured as he is by a host of designing capitalists trying to deprive him of the fruit of his labor, his only protection being the patent laws. The individual who touches the public heart as a struggling mechanical genius, who will be crushed if not protected, does exist, but he is very rare, and one of the reasons why he has no chance is because of the multitude of pretenders. Remove the vast accumulations of so-called inventions upon which patents have been granted which have neither merit nor novelty, then there would be some chance for the public to find the real inventor and reward him in such a manner as would ease the public conscience. This might be done by either granting a patent where a real invention has been made (such a patent would have a value which under the present conditions is hardly possible) or the claims of an inventor could go before a commission composed of business men, each of high standing in his line of work, and so constructed as to cover the whole field of applied mechanics and processes of manufacture, who would administer to the inventor from the public purse a direct reward, which would be in proportion to the merit of the invention. There would, no doubt, be many objections to such a scheme because of the multitude of patents issued on what are not in any sense inventions, the holders of which

reaping where they never did any sowing. All that multitude of patentees, including those whose business it is to prepare the way for inventors to obtain patents and protect them in the sole use of them, and the still greater multitude who expect to be patentees, although in no sense inventors, will have many objections to any method such as I propose, by which the real inventor might be able to bring himself into the light and receive a just reward for what he has done. It is because of this strong opposition that I have brought this subject before the Technical Society, in the hope that it may be fully discussed. Some of the most prominent men in the application of the mechanical arts to our industries are beginning to look for some way whereby this huge incubus can be lifted from the free use of mechanical combinations that have been free until some clever patent expert, whose client wanted a patent, was able to so word a claim as to tie up the use of some well-known device. It may be claimed that the examiners at the Patent Office are competent to protect the public from the evils I have pointed out, but these men know nothing of what is going on in the great industrial establishments, where the real inventions, that result in progress, are being made every hour of the day with no thought of protection from patents. The Patent Office examiner is concerned only to find whether someone has not patented the same thing or combination of things before. The real inventor has a harder time to satisfy the Patent Office expert than the combination man. The inventor must have something that is entirely new, something which the Patent Office, in all its years of collecting, has never had before, but the combination man has only to make a new arrangement of words to describe his claim. The courts also are supposed to protect the public against unjust patents, but, besides the expense involved in defending an action for infringement, there is the difficulty of procuring evidence of use. If one has to go back several years for it, it is often difficult to obtain. Drawings, made without any thought of their being required for anything except to get out the work by, are often found without date. Instructions are often given to carry out work in a certain way without any evidence being preserved of the when and why of such instructions. Those who are engaged every day in making all sorts of mechanical combinations to fulfill requirements in the specifications that describe the work under the various contracts they are endeavoring to execute have no visions of fortune through patents coming to them. They do not consider themselves inventors, and they never think of evidence in regard to their daily

work. Yet these are the men who have advanced the mechanical arts to the place they occupy in the industrial world of to-day.

I trust that this imperfect presentation of this most important question will be carefully considered and discussed by the members of the Technical Society. We are all more or less interested, either directly or indirectly, in patents. My side of this question is not the popular side. I have long felt it to be the right side. I have brought it forward at this time not on any sudden impulse. It has been a growing conviction with me for the past twenty years that a change is needed in the patent laws, and that this need is growing more urgent every day.

PATENT LAW ADMINISTRATION.

By John Richards, Past-President Technical Society of the Pacific Coast.

[Read before the Society, November 6, 1903.*]

The present paper has been produced a piece at a time, as opportunity permitted, and it will lack the order and sequence desirable in such contributions. For one thing it will discuss but briefly the effect of patent grants on industrial development, which should have been a main theme. The reason is that this subject was reserved as a separate part, and is shut out for want of space and time; also, because it is not demonstrable by facts and can safely be left to inference.

I have read with interest and approval the remarks on patents for inventions presented at the last stated meeting of the Society by my friend, Mr. Dickie, and, as this paper was brief, I venture to submit something further in respect to the patent system of this country, with some remarks upon the same subject as represented in other countries.

At the beginning I am willing to concede the abuses that arise out of procedure, meaning by this term the conduct or administration of the patent laws, but I must contend, on grounds of natural right as well as of expediency, that the policy of such grants is well-established by the fact that all countries where there are industrial interests to promote have patent laws, Holland excepted.

In Switzerland, where we may look for the most enlightened laws and policy in such things, the patent laws were for a time abrogated, and again restored on nearly their former basis, so that the equity and expediency of such grants can scarcely be called in question.

There is also the further fact that British laws, from which the system originated 280 years ago, have changed but little in all that time. I have brought with me this evening copies of British patents more than 200 years old,—in one or two cases more than 250 years old,—from which it may be seen that no great change has been made in all that time.

From England the system of patent grants for inventions spread widely over the world, our own dating back something more than a century, the present indices reaching to 1790. It is an interesting study to examine the development of this patent

*Manuscript received December 1, 1903.—Secretary, Ass'n of Eng. Socs.

system and the impediments which had to be overcome because of the paucity of technical knowledge and skill required to administer such a bureau in a new country, where science and the technical arts had a narrow foothold until comparatively recent times.

It will be remembered, no doubt, by many here this evening that down to 1870, or later than that, each inventor had to supply a model of his invention, in order to enable the officers of the Patent Office to understand its nature and its manner of operation. Not only this, but the drawings supplied had to conform to the model, and, as models were naturally crude, the result of this can be imagined. No other country, that I am aware of, except Canada, adopted such a feature, but in Canada the drawing and model were not required to correspond, so the model happily dropped out, though a little later than in this country.

This method, which called out a good deal of ridicule in other countries, has left us a legacy of useless lumber, which still occupies a good deal of room in the cramped space where the Patent Office work is carried on. Some of these models have interest historically and some of them are well made, but destruction would be a proper treatment for three-fourths of the whole.

The operation of the patent laws went on with measurable uniformity in different countries until within a few years past, when the German Bureau initiated a reform that will no doubt extend to other countries where technical knowledge is sufficiently advanced to permit such a system. This change is fundamental in its nature, but not very easy to explain in a popular way. It would, no doubt, satisfy my friend, Mr. Dickie, but it is not, however, likely to prevail here during his time or mine. It consists in a measure of novelty and utility on grounds almost the reverse of present practice in this country. Our laws permit or grant patents on the means or agents of production only; that is, on contrivances or discoveries that produce results, and particularly bar patents on principles or on modes of operating. This, it will be seen, opens the door for endless patents on nearly the same thing, with slight differences that often turn upon mere phrases of speech.

The German Government grants patents on results, or, in their terms, on "new technical results," paying but little attention to means or implements. Claims to express compendiously the subject-matter of an invention are limited to one that must involve what is called a "unitary concept." Other claims may be added, not more than three, explanatory of the first. This plainly involves a complete change of system. The controversy concerning Mr.

Dickie's bulkhead doors could never have arisen under a law and practice of this kind.

It would be an enormous innovation in this country for our astute patent agents, who can write twenty permutation claims on a nutcracker, but it is an advance to a higher plane, is logical and must commend itself to all who will analyze the true spirit and intent of patent grants for inventions. This juggling system of "permutation claims" is a distinguishing feature of modern practice in this country. It is a device that had its origin with patent agents, and because the claims in American patents were construed separately and independently. It is the reverse in England, where a patent falls with each and any of its claims; and in France, where, until very recently, a patent required no claim at all separate from the body of the specification. This latter system permitted full discretion to the courts, and this discretion, I am glad to say, has been seldom abused.

Our own courts have to deal with words and cunningly devised phrases instead of the essence, nature and scope of an invention, and, having a dread of subjects they cannot possibly understand beyond a construction of terms, the justices are apt to follow each other in their decisions on any issue. This was the case in the celebrated Woodworth patent suits early in the last century, when there were twenty-two suits at law over the invention of a "combination of feeding rollers and rotary cutters," which invention you will find in the British patent of Bentham of 1793, among the copies present this evening.

I am recounting these features of practice for two reasons: First, in order to show how difficult it is to administer the patent laws, and especially procedure in the Patent Office; and, secondly, to invite comment on some means of attaining a more intelligent and just procedure in that department.

The statute law relating to patents is printed on 32 small pages containing about 15,000 words, and is, in itself, quite simple and understandable; but this law is supplemented by endless decisions that attempt to fit the application of these laws to the circumstances of industrial inventions, and it is doubtful whether any human power could codify this maze and bring it into a harmonious relation with the arts.

The "Rules of Procedure," 214 in number, emanating from the Commissioners of Patents and their advisers, is a more extensive matter than the law, occupying 100 printed pages and about 47,000 words, much of which should be embraced in the statutes. These rules are intended for the instruction and guidance of the exam-

iners and patent attorneys. They are often changed and extended to meet the constantly recurring problems that arise in an attempt to fit laws and administrative rules to science and the arts, which is, in the nature of things, impossible.

This impediment is fundamental and perhaps insuperable. The two things cannot be assimilated. Science and the arts are computable and exact. They deal with definite dimensions, fixed natural laws and skill, the latter meaning a personal recognition and acquaintance with these qualities, or quantities, and with the modes of their operation. Statute law is inexact, uncertain and mutable. It does not deal with dimensions or exact quantities of any kind; not even, except in an indirect way, with modes of operation. One may read through a law treatise, even on patent law, and not find in it a single thing that has a base in anything exact and proved, except, perhaps, a chemical formula. Men skilled in statute laws are seldom or never qualified to deal with the technicalities of the industrial arts, and, consequently, not capable of determining the nature, scope and relations of inventions.

Conversely, those skilled in the arts and accustomed to the exact results of science are apt to look with indifference and suspicion on the unstable laws and procedure relating to patents for inventions. The basis for this work must be facts, measurable and computable; things must co-relate, must have constant sequence and must be uniform. Law and the practice of law are none of these things, but are arbitrary, uncertain and frequently illogical.

It is not easy to make the difficulties of administration clear, but your own consideration of them will, no doubt, confirm the fact that neither this nor any other Government has resources from which to draw officers to administer a patent bureau according to the spirit and intent of the laws.

Germany, which established excellent and numerous technical schools about 50 years ago, is at this time nearer than other countries to providing a corps of officers competent to pass upon and award patents for inventions. These technical schools had no marked influence over the industries of the country for 30 years or more, but now we can see their effect in many ways. In Saxony alone there are 287 industrial schools. The chemical industry will show the influence of this kind of training.

In Germany there are more than 6000 establishments making chemical products, employing 135,000 workmen. One of these, at Manheim, which I have seen, employs 6000 workmen and 148 chemists, besides the clerical force. With few natural resources

for chemical products, Germany managed to send into this country last year $14,000,000 worth of such manufactures.

Under such circumstances, where there are thousands of qualified men available to conduct this department in a patent bureau, we should naturally look for good practice; and, as I have before pointed out, their system is likely to produce imitation in other countries.

It is likely that an impediment to this system will be found in its paternal nature. The law provides that each patent granted must include an "invention," and, as no law can define what an invention is, this point is left to the decision of the officers of the bureau at Berlin, qualified by the provision before named, that an invention must produce a new "technical result" and consist of a "unitary concept."

This is vague, but is as far as law can go. It reaches the point where personal knowledge of the arts must begin; in other words it is the point where technical knowledge and impartial administration must take up the work and brings us to what we call "procedure," in which a German officer is supposed to ignore nationality, forego his prejudices and act impartially. Time will show whether this be possible.

In this country the enormous activity of industrial production furnishes a field that absorbs the technically trained people, and few are available for the Patent Bureau. On the contrary the legal profession is overflowing and aggressive, and, as patents for inventions are commonly understood as a matter of law instead of technical discrimination, the result is what Mr. Dickie complains of in his paper.

An examiner-in-chief, of which there are three who sit as a board of appeal in contested cases, receives the sum of $3000 a year; a principal examiner, the head of a division, gets $2500; a first assistant examiner, $1800 a year, and from this the salaries run down to $1200 a year for fourth assistant examiners.

There are 200 officers who come under the head of examiners, and in all between 700 and 800 people employed by the Bureau, a large proportion of whom seem to come from the New England States.

It is an amazing example of routine work, done by rule and apparently without personal discretion—by rules that have grown out of the conduct of the office and the circumstances of procedure.

Changes—even the slightest—are ventured upon with timidity, and, while it is easy to discern much that seems illogical and wrong, it would be hard to see how any successful change can be made

without starting at the very beginning with a new law relating to patents for inventions.

The functions of examination and rejection are the salient features of our patent system, and, consequently, must form an important part of this paper. Examination, so far as advisory, is a proper and useful function of the Bureau and its officers, and is more complete in this than in any other country at this time, so far as the records of the Patent Bureau furnish a basis; but rejection is quite another matter.

It is this paternal and arbitrary procedure exercised by the officers of the Bureau that has led to a common belief that a patent is an "act of grace" and a favor or privilege conveyed and confirmed by the action of the Government.

This idea is a logical sequence, because rejection is naturally a corollary of "confirmation," and no one can well conceive of a power to destroy without a corresponding power to sustain.

The rejection of a patent is in its nature a paternal act, wherein the Government assumes a function that properly belongs to the citizen. The applicant is not permitted to use his own judgment as to what he can maintain and defend, but is taken care of, so to speak, and instructed as to what he shall have the privilege of maintaining, by the judgment of an officer who can destroy but cannot confirm. This is paternalism and establishes a common conclusion in the minds of applicants, and, indeed, in the minds of all except those who have studied the patent laws, that they are to receive with a patent a confirmed right.

Patent agents all over the country will bear evidence to the existence of this opinion among their clients, who look upon the examiners as holding in their power a favor to be bestowed or withheld. "Get all you can" are the instructions, but these same people are generally very cautious respecting their claims in other countries, where personal responsibility is the same. It may at first thought seem a strange proposition that the rejection of patents should increase the number and lower the character of applications, but I am satisfied that it does so.

Thousands of applications are made that would never appear if the applicant and his attorney were made responsible, as in England, for the scope and novelty of inventions as presented to the Bureau. I judge of this matter by the fact that patents are more respected there than here, and are as seldom repeated and more often sustained in the law courts.

I am aware that this has been disputed, but I speak from an

experience of thirty years or more in both countries, dealing with articles of manufacture, many of them protected by patents.

What the result may be in Germany and in some other countries that are extending their patent bureaus to include a corps of examiners one cannot conjecture at this time, but it is highly probable that this paternal system will not in the end have the effect desired, unless such desire is to destroy property in invention, which to an increasing number of people at this day would be a welcome consummation.

Returning to our own Patent Bureau, the paternal idea which manifests itself by rejection leads to certain administrative anomalies.

For example a primary examiner, instead of acting in what may be called a professional capacity, performs routine duties in which his individuality is usually eliminated. He does not even sign his decisions and has no power to amend them; no matter how mistaken they may be they must go permanently into the record.

But, strangest of all, he exercises a "triple function," so to speak, being a whole tribunal in himself, acting as witness, counsel and judge. He prepares the evidence, presents it as attorney for the Government as against the client and then passes judicially upon his own findings by deciding whether the applicant shall or shall not have the privilege of defending his claims in the law courts. These duties, instead of being professional and advisory, are arbitrary; they consequently fail to command the confidence of inventors and put the Bureau in a false position before the country.

At present, in some European countries, where examinations are made in respect to novelty as well as to form, it is common to have a communication from the Bureau pointing out that an invention is in part or wholly anticipated, or that the specification is too broad in its statements and claims, but there is no "rejection," except in Germany, nor is there authority for that. The applicant can proceed at his peril after such notice, on his own responsibility, but, of course, will always amend his specification to avoid references which he or his attorney had failed to consider.

I am inclined to think that our patent system, or the manner of its administration, has, in some cases, exercised a restraining influence on certain arts.

As a case in illustration: Among those interested in the subject it is a matter of common knowledge that inventions pertaining to hydraulics have for many years past met with scant encouragement in the American Patent Office, and that, as an example, our

water-wheel practice, a very extensive interest, is in certain types distinctly behind that of France, England, Germany and Hungary, a fact that appeared when the Niagara Commission met at London in 1890 to consider water wheels for the Niagara Falls scheme. American makers presented no plans that the Commission considered, or even mentioned, in their report, except one tender from San Francisco for tangential wheels, which I had the honor to prepare.

Pressure turbine practice in this country, except as to one type, the centripetal or central-discharge one, came from France, and the best examples in use here were made under the patents of Fourneyron and Jonval, while the Girard type, that was best suited for use at Niagara and for high heads, was not until 1893 made in this country at all, and was then so badly made as to fail, so that no impulsive-acting wheels of any kind were made, down to the evolution of the tangential type on this coast.

How a country where so much water power is employed under all kinds of heads and conditions could go on until a few years ago without any manufacture of the type of water wheels known as the Girard class of unfilled or partial turbines, one of the most common in Europe, will appear if we examine the history of some early inventions here.

In February, 1853, fifty years ago, Mr. Jearum Atkins, of Illinois, I think, filed in the Patent Office at Washington an application for an improvement in water wheels of the unfilled or impulse type, and in his specification set forth, in the form of a well-written treatise, the principles on which his wheels operated.

This application was promptly "rejected." No unfilled turbine had been seen before, and Mr. Atkins, being a poor man without resources, and an invalid besides, was not able to prosecute his case by appeal or otherwise, and, as the patent could not issue because of "rejection," he was unable to work his invention, except to make one very successful wheel; so the invention was strangled, so to speak, by rejection.

About 1860, seven years later, Messrs. Escher, Wyss & Co., of Zurich, Switzerland, began making water wheels of the same type, and the practice rapidly extended all over Europe, especially in France and Switzerland, and, as I have remarked, came back to this country in 1890 through the plans of the water wheels at Niagara, which were made from drawings furnished by Messrs. Faesch & Picard, of Geneva, Switzerland, who, with four or more other European firms, tendered full designs for the construction of these wheels.

In 1875 Mr. Atkins's invention was somehow resuscitated at the Patent Office in this country and a patent was issued to him, but too late to do him any good or to aid in founding the manufacture here. Mr. Atkins, when I last heard from him, was living at an advanced age in the Mechanics' Home in Philadelphia.

He was an original inventor, perhaps the first to discover and explain what are called impulse or open-turbine wheels, in which the discharge vents are larger than the inlet ways, and was the first, in this country at least, to lay down in a clear manner the principles involved in this kind of water wheels, which include the tangential type extensively made and used on this coast.

Suppose the patent of Mr. Atkins had been issued in 1853, even with all the objections that were urged against it in the Patent Office, no one will doubt that the inventor's representations and his better understanding of the subject would, in either a business way or even in suits at law to defend his invention, have been quite sufficient to work and sustain his patent; and if this had been done, this country would have reaped a great reward from the invention.

It is not contended that the examiner should have known that a turbine water wheel would operate when not filled and when the discharge passages had double the area of the inlet ways. A recorded opinion to that effect would by no means have destroyed Atkins's patent if it had been issued at his request, but "rejection" took away his power of utilizing the invention and destroyed it, whereas it is quite sure the courts would have sustained his claims, notwithstanding the action of the Patent Office.

I could go on and show that in centrifugal pumps, gas engines and other important manufactures procedure in the Patent Office has hindered progress. Just at this time I have failed to have a distinction made between impulsive-acting and pressure fluid machines operating by steam. Both types seem to be in one class, although their manner of operating is essentially different.

It is like the old problem of 1853, or, rather, is the same problem over again, and the result is that there is not a manufacture of impulsive-acting steam engines in this country that is not either an imitation of European practice or paying tribute to foreign inventors. The first successful engines of this type, of which I have any knowledge, were made about eighty years ago by William Avery, of Syracuse, N. Y., an uncle of Prof. John E. Sweet, who made fifty or more, and, as I have just remarked, there is not at this time a separate division in which these engines could be classed in the Patent Office.

In 1895 a distinct invention in ignition apparatus for gas engines was made by Mr. Geo. E. Hoyt, of San Francisco, in which the "time function" was regulated by resistance and distance of flow of the gases into a tube, having a small bore about one-thirtieth of an inch in diameter. This invention was presented and persistently prosecuted before the Patent Office for two years. The inventor sent to the office tubes 5 inches and others 30 inches long, with affidavits to show that both had been on the same engines under the same conditions, and that it was the contracted bore, resistance and consequent velocity of flow into the tubes that determined the time point of ignition.

The claims were rejected by the primary examiner on irrelevant references, and by the examiners-in-chief, and was abandoned because the parties in interest concluded, and yet believe, that the invention was opposed on technicalities and not considered on its merits as an invention. This was the last application for letters patent filed in this country by that company. They are still prominent makers of gas engines here.

One examiner will be said to act carefully and impartially; in another division, it will be said, nothing escapes rejection, and attorneys dread to send in cases. Any experienced solicitor of patents will confirm this statement. Its significance lies in the fact that the present rules do not provide impartial administration.

There is no intention to disparage or underrate the eminent attainments of a large number of officers in the Bureau, but even these are bound by a routine of rules and precedents that prevent personal and responsible action in technical matters. They are bound to consider terms and forms of speech that are purposely made entangling and obscure, and not the essential facts.

In chemistry and other of the sciences that can be called exact, the procedure in the Patent Office is all that could be desired, and it is a wonder that the same or corresponding ability cannot be commanded for what we may call the dynamic and mechanical divisions. Imagine, for example, in chemistry or electricity, the want of distinction between two qualities or forces so unlike as the pressure and impulsive action of fluids.

I do not feel qualified to suggest a remedy for the features of our patent system that have been criticised, but strongly suspect that the German laws and procedure are a distinct advance in some of the objects to be attained by a patent system. I believe that the number of patents granted in this country, about half a million a year, could be well reduced to one-third as many by the requirement that each patent should relate to a new "technical result,"

and not a means alone; that patent attorneys should not be admitted to registry or to practice in office procedure unless competent and qualified, as in other professions; that the actions of the primary examiners, which are now a part of the permanent record, should, with amendments, be printed with each patent; that the power of final rejection be taken away from the primary examiners and exercised by different officers, capable of judging impartially of new technical results; that the appeal tribunals of the Bureau, now wholly inadequate, should have more time and facilities for their actions; that the salaries of the chief and first-class examiners should be doubled, so as to command higher technical qualifications for this intricate and responsible work.

There are now, I believe, about seventy legislative bills before Congress relating to the Patent Office, most of them bad; but, this being a national matter, and as we have no national representatives in Congress, such legislation receives but little attention, and, with a surplus of between four and five millions of dollars lying idle in the United States Treasury, the Patent Office is crowded for room and without facilities for conducting its enormous business, constantly increasing in volume, and certainly without a corresponding useful effect on our industries.

In 1902 applications for patents in this country numbered 49,499. Of these, 27,776 were passed, the rejected and abandoned cases being 21,714. Expired patents, granted in 1885, were 21,714, which shows an increase of more than 6000 since that time. Where this is to end no one can foresee, unless some means is discovered of confining patent grants to those who produce some new practical result and whose claims can be understood by the public.

Of patent agents there are now about 3000 registered in this country, which number, divided into applications filed, gives less than eighteen cases a year for each and for patents granted nine for each attorney, which should return the munificent sum of about $200 a year for fees.

The criticisms of Mr. Dickie are well taken, but it is not the laws that are at fault so much as the administration of them.

Finally, I will venture the opinion that we are at the beginning, or a little beyond the beginning, of a war upon property in inventions, a war which will no doubt be conducted with extreme subtlety by those who own large amounts of capital and who recognize that as the only interest that should absorb the earnings of industrial production.

As signs in this direction may be mentioned the erratic administration mentioned in this and in Mr. Dickie's paper; the want

of room for the Patent Bureau and especially the paucity of legislation and attention given to this subject; the character of the bills now before Congress, and the growing opinion, if not belief, among large owners, that small or individual enterprises such as are founded on patents should not exist.

The first movement in this war against invention will be to render patent grants unpopular, and finally obnoxious, by representing them as monopolies and by encouraging bad administration.

The honest administration of the Bureau and of the appellate and circuit courts is seldom called in question, although dealing with vast and intricate interests, and this circumstance has, no doubt, warded off attacks that would otherwise have been made upon the system.

This claim of honesty and pure administration, however great the errors made, is one of especial weight when so much of an opposite nature characterizes our time, and we may be excused for some congratulation over the fact that engineers and mechanics deal with truth and ascertain facts, and that even the romancers never choose their villainous characters from these callings.

OBITUARY.

Alphonse Fteley.

Member of the Boston Society of Civil Engineers.

[Read before the Society, December 16, 1903.]

Alphonse Fteley was born in Paris, France, April 10, 1837, and died June 11, 1903. He was educated in the Government schools and obtained an academic degree from the University of France. Subsequently he attended the École Polytechnique in Paris, was graduated therefrom in 1859 and at once began his professional career.

For six years he was engaged on varied engineering work in France, after which he came to the United States in 1865. His first work in this country was as a mechanical draughtsman on the construction of machinery for river steamboats, and at the same time he was engaged in the study of the English language. The next year he entered the office of the late Mr. William E. Worthen, where, as general assistant, he was employed on civil, hydraulic and mechanical engineering until 1870. He then opened an office in New York City for general engineering practice, especially in the line of hydraulic engineering.

While in general practice, he was at times professionally associated with Messrs. William E. Worthen, James P. Kirkwood and other prominent engineers. At one time, while assisting Mr. Worthen in experiments upon the efficiency of the pumping engines of the Brooklyn Waterworks, at Ridgewood, he contracted, by overexertion, a peculiar heart trouble, which weakened his physical powers in some respects and made more difficult his life work.

In May, 1873, Mr. Fteley was called from New York to Boston to take charge, under Mr. Joseph P. Davis, City Engineer, of the construction of the Sudbury River Waterworks. The construction of these works, which was somewhat delayed by many additional investigations, required by the city government of Boston, continued until 1880. The works consisted of an aqueduct 16 miles long, including in its length tunnels, arch bridges and siphons, storage reservoirs and other works pertaining to a water supply. His success in the construction and in the design of many important features of these works gave evidence of his eminent skill as an engineer.

It was during his connection with this work that the accurate gaugings of the flow of the Sudbury River, which have since become

classic, were inaugurated, and during this time also, in connection with his assistant, Mr. Frederic P. Stearns, he carried out important hydraulic experiments upon the flow of water over weirs of various forms, upon the flow through aqueducts and upon the accuracy of current meters. The results of these experiments were contained in a paper presented to the American Society of Civil Engineers in 1882, for which the Norman medal for that year was awarded.

In April, 1880, when the Sudbury Works were substantially completed, Mr. Fteley accepted a position as Chief Assistant City Engineer of Boston, the position having become vacant by the resignation of Mr. Davis as City Engineer, and the promotion of his chief assistant, Mr. Henry M. Wightman, to his place. While occupying this position, he was engaged upon the design of various works for the city, including important parts of the main drainage, water supply and park systems.

On January 23, 1884, the Aqueduct Commissioners of New York, who were about to begin the construction of new works for increasing the water supply of that city from the Croton River, appointed Mr. Fteley to the position of Principal Assistant and Executive Engineer, under Mr. Benjamin S. Church, Chief Engineer. This title was subsequently changed to that of Deputy Chief Engineer. On July 21, 1886, Mr. Fteley was appointed as Consulting Engineer.

That Mr. Fteley's previous experience was of especial value is indicated by the report of Mr. Church, dated January 1, 1887. He says, "As Principal Assistant and Deputy Chief Engineer, Mr. Fteley has assisted me throughout the preparation and organization of the work. I had especially put under his able direction the professional study connected with the design of the aqueduct and of Quaker Bridge Dam and the preparation of the contracts and contract plans."

On November 21, 1888, Mr. Fteley was appointed Chief Engineer of the Aqueduct Commission, and continued in this position until failing health made it necessary for him to resign, at the end of 1899. While occupying this position, Mr. Fteley had charge of the design and construction of very important works, including the Jerome Park Reservoir and the New Croton and other dams upon the Croton River and its branches. All of these, except the Jerome Park Reservoir and the New Croton Dam, were completed before his resignation and successfully stood the test of actual use.

As there have been criticisms regarding the selection of the site of the New Croton Dam, it is well to state that Mr. Fteley, in

a report to the Aqueduct Commissioners, dated October 8, 1890, advised the building of a dam farther upstream, and not at this place, but his advice was not followed.

In addition to the important permanent positions which have been mentioned, Mr. Fteley had a large consulting practice in connection with water supplies, sewerage and otherwise. Among the more important positions held were those of member of the Technical Advisory Committee of the new Panama Canal Company, Consulting Engineer for the Metropolitan Water and Sewerage Board of Massachusetts, for the first Rapid Transit Commission of Boston, and in connection with the additional water supplies of Newark, N. J., and Rochester, N. Y.

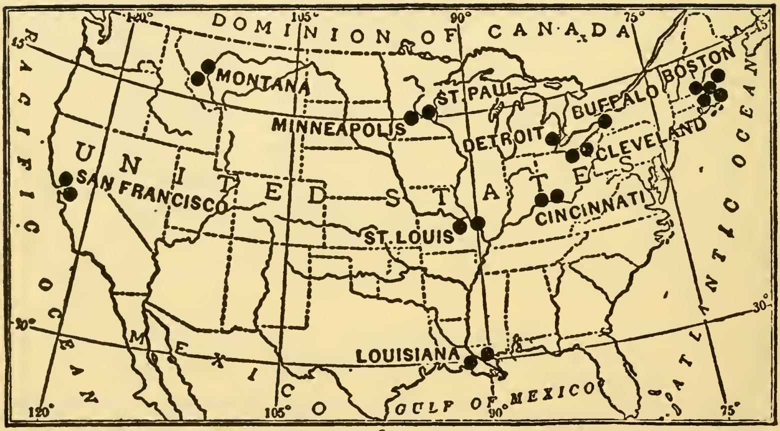
Mr. Fteley joined the Boston Society of Civil Engineers on June 8, 1874, and, notwithstanding his absence from Boston for the nineteen years preceding his death, he retained his membership and his interest in the Society. He joined the American Society of Civil Engineers in 1876, and was its President in 1898. He was elected a member of the New England Waterworks Association in June, 1885, and was made an honorary member in September, 1902. He received the degree of Master of Arts from Columbia University in 1898. He was a member of the Century Club of New York.

After retiring from active practice Mr. Fteley's failing health required him to avoid all physical exertion, but his mental powers remained undiminished and he attended to a limited amount of consulting work.

On May 19, 1898, Mr. Fteley met with a very great loss in the death of his wife. He leaves one daughter, Miss Estelle Fteley, and four stepchildren, Miss Marie Breuchaud and Jules Breuchaud, of Yonkers, N. Y.; Mrs. George S. Rice, of New York City, and Mrs. Andrew Cunningham, of Oakland, Cal.

He possessed natural ability of a high order and was thoroughly educated for his profession; he entered upon the study of any problem presented to him with unbiased mind, and, having the power of close and continued reasoning, he reached conclusions that were sound. Naturally, with these attributes, he achieved a high rank in his profession, and stood among the foremost in his specialty of hydraulic engineering. Being endowed with a very equable and sympathetic temperament and having pleasing manners and address, he won the warm and lasting regard of all with whom he was brought in association—those for whom he worked as well as those who worked with and under him. His character was altogether admirable.

Joseph P. Davis,
Frederic P. Stearns,
George S. Rice,
Committee.


DOMINION OF CANADA
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Association of Engineering Societies.

VOL. XXXI. JULY, 1903. No. 1.

PROCEEDINGS.

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, CAL., JUNE 5, 1903.—Called to order at 8.30 o'clock P.M., by President Henny.

The minutes of the last regular meeting were read and approved.

The following named persons were elected to membership after a count of ballots:

Member—Charles List, civil engineer.

Associates—George Stone, President Portland Cement Company, San Francisco, Cal.; Rudolph J. Taussig, President Mechanics' Institute, San Francisco, Cal.; S. Giletti, contractor, San Francisco, Cal.

Mr. Marsden Manson and Mr. C. E. Grunsky discussed the various projects for a water supply for the city of San Francisco, relating in some detail the present means of the Spring Valley Waterworks and the probable methods of increase in the supply with the growth of the city. The projects of a municipal waterworks on a large scale, with water brought from the Sierras, was fully discussed and the advantages of such an attractive supply brought out.

President Henny discussed the proposition from an economic standpoint, and thought that the vast storage of the lower San Joaquin and Sacramento Rivers might be drawn on for an ample and healthful supply, and that with facilities for a proper filtration there appeared no reason why this supply, so favorably situated, should not be utilized.

His remarks were not offered as a criticism, but were in the nature of suggestions to draw out a discussion in this particular line of argument.

This important subject was discussed at length by a number of the members, until, at a late hour, the Society adjourned.

The announcement was made officially that, according to custom, the regular July meeting would be dropped on account of the summer holidays.

OTTO VON GELDERN, *Secretary.*


DOMINION OF CANADA
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BUFFALO
DETROIT
CLEVELAND
UNITED STATES
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GULF OF MEXICO
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Association of Engineering Societies.

Vol. XXXI. AUGUST, 1903. No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., August 7, 1903.—Called to order at 8.30 p.m. by Past President Grunsky. The minutes of the last regular meeting were read and approved.

Mr. C. E. Grunsky addressed the members informally, taking for his subject the impressions made upon him by the engineering works of the Eastern states while visiting them recently. He described with much detail some of the principal structures visited, such as the Croton Dam, and gave some very interesting information about them. His subjects were illustrated by a great many photographs taken by himself, which, during his discourse, were passed around to the members.

It was announced subsequently that one of the charter members of the Technical Society, George F. Allardt, died at his residence in Oakland several days ago. The Secretary sent an appropriate floral offering in the name of the Society, and has received the following answer:

To the Technical Society:

Accept my thanks for the beautiful wreath of maidenhair fern and roses sent by the Society, as it expressed to me the high esteem in which Mr. Allardt was held.

Respectfully yours,

Mrs. G. F. Allardt.

Sunday, August 9th.

The Secretary has also reported to the Board of Directors that he had communicated with a member of the family for a history of the deceased engineer, which is to be published as an appropriate memorial in the Journal of the Association of Engineering Societies. This will be placed before the Society as soon as it has been received by the Secretary.

It likewise became the sad duty of the Secretary to report to the Board of Directors the death of our fellow-member, Frank B. Morse, who died in the city of Mexico on February 18, 1903, where he was taken early in the November previous, suffering from complications that resulted in cirrhosis of the liver, of which he died. He was 51 years and 3½ months old. At the time of his illness he was the superintendent of the Corejo Colorado Mines and Mill at Ocatlan, and had also under lease other mining

and mill properties at El Parian. He left a wife, two daughters—one the wife of Mr. Chas. H. Andros—and a young son. The widow now resides at Gloucester, Mass.

Mr. Morse was a charter member, and is probably known only to those who were members in the early history of the Society. Although in a foreign country for many years, he always kept in touch with the Technical Society and its members, who will regret the loss of one so loyal and faithful to them.

Without further business the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies.

Vol. XXXI. SEPTEMBER, 1903. No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 16, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President Ira N. Hollis in the chair. Forty-five members and visitors present.

The record of the last meeting was read and approved.

On motion of Mr. Adams, the thanks of the Society were voted to Lieutenant-Colonel W. S. Stanton, U. S. A., Lighthouse Engineer, and to Mr. Royal Luther, Superintendent of Construction; also to the Hon. James Donovan, Superintendent of Streets of Boston, and to chief clerk, Mr. W. J. Sheils, for courtesies extended to members of the Society on the excursion of August 22, 1903, to "Boston Light" and to the new lighthouse under construction at "The Graves."

The Secretary read a communication from the Committee of the American Society of Civil Engineers on Universal Exposition at St. Louis in 1904, extending to the members of this Society a cordial invitation to avail themselves of the conveniences of the headquarters to be established by the American Society at St. Louis during the Exposition. The Secretary was directed to acknowledge the receipt of the communication and express the thanks of the Society for the courtesy extended.

Communications were read from Mr. W. P. Morse and G. A. Nelson, members of the Society, submitting designs for a Society badge.

A general discussion followed on the advisability of the adoption of a badge by the Society, and, on a motion, the sense of the meeting was taken, which was almost unanimous in favor of the adoption of a badge. It was finally voted that the Board of Government issue a letter ballot on the question of the adoption of a badge and calling for an expression of the preferences of members among the five designs already submitted, or for others which may be submitted. The Secretary was also instructed to have sample badges made of the two designs presented at this meeting.

Mr. William O. Webber then read the paper of the evening, entitled "Rainfall and Runoff of New England and Atlantic Coast Streams." An interesting discussion followed, in which Messrs. Charles T. Main, Richard A. Hale, Dwight Porter, Freeman C. Coffin and Lewis M. Hastings took part.

Adjourned. S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

565TH MEETING, ST. LOUIS, SEPTEMBER 16, 1903.—Held at the Club Rooms, 709 Pine street, at 8.15 P.M.; Vice-President Ockerson in the chair. Present twenty-three members and four visitors.

The minutes of the 564th meeting were read and approved.

The minutes of the 350th and 351st meeting of the Executive Committee were read.

The applications for membership of Messrs. F. C. Albrecht, Edw. B. Day, John V. Hanna and E. F. Wiederholdt were read and referred to the Executive Committee.

The death of Mr. Edmund D. Libby, who died April 24th, at Concord, N. H., was announced.

The Secretary then read a letter from Mr. R. H. Phillips, informing the Club that the Engineering Association of the South intended to hold its annual meeting at St. Louis during the World's Fair. It was moved, seconded and carried that the Secretary be instructed to invite the said Association to make use of the Club's headquarters during its stay in St. Louis.

The paper of the evening, by Mr. Percival E. Fansler, on the "Indiana Interurban Systems," was then read. The paper was illustrated by a number of charts and sketches, and dealt principally with the power generation and transmission features of the system, with special reference to some very exhaustive tests of the economy of the generating and transmission systems. It was found that about 3.5 per cent. of the energy in the coal reached the car, while about 53 per cent. of the energy delivered to the generators reached the car. The longest transmission on the system is thirty-three miles.

The paper was very generally discussed by the members present, after which a vote of thanks was tendered Mr. Fansler for his instructive discourse.

Upon motion the meeting adjourned to the lobby, where a light lunch was served.

H. J. PFEIFER, *Secretary.*

Association of Engineering Societies.

Vol. XXXI.	OCTOBER, 1903.	No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, October 21, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M.; President Ira N. Hollis in the chair. Ninety-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Harold W. Horne and James W. Pierce were elected members of the Society.

The President announced the death of William C. Ogden, a member of the Society, which occurred on October 12, 1903, and on motion the President was requested to appoint a committee to prepare a memoir.

The President has appointed as this committee Messrs. S. Foster Jacques and Arthur W. Dean.

The thanks of the Society were voted to Professor Hollis, Professor Johnson and Mr. Wason for courtesies extended to members on the occasion of the visit to the stadium under construction on Soldiers' Field for Harvard College.

Mr. Kimball, for the committee appointed to revise the By-laws of the Society, submitted the following report:

Boston, October 1, 1903.

To the Boston Society of Civil Engineers:

Your committee on revision of the By-laws respectfully report as follows:

We recommend the following amendments to the By-laws:

Strike out Section 5 and substitute therefor the following:

5. Nomination and Election of Officers.—A nominating committee of eleven shall be chosen at the regular meeting in December. Two of the members of the committee shall be the two most recent living past-presidents; the other nine members shall be chosen by letter-ballot, each member of the Society voting for one member of the committee on a card to be furnished by the Secretary with the notice of the December meeting; this card to contain a list of members ineligible for the committee. The nine eligible members receiving the highest number of votes shall be declared elected; and in case of a tie the choice between the members so tied shall be determined by lot. In case any member shall refuse to serve, the member receiving the next highest number of votes shall be declared elected.

No officer of the Society shall be eligible to membership on the committee, and no member, other than the two past-presidents referred to above, shall be eligible to serve on the committee in successive years.

The nominating committee shall meet at the call of the senior of the two past-presidents; and seven members shall constitute a quorum. It shall submit to the Secretary, within twenty days after the December meeting, the name of one candidate for each office to be filled by ballot at the annual meeting. The Secretary shall send to

each member of the Society, not later than January 20th, a copy of the nominations made by the committee.

At any time previous to February 5th, any ten or more members may submit to the Secretary additional nominations, signed by such members, and accompanied by acceptances from the members so nominated.

Letter-ballots shall be sent by the Secretary to each member of the Society, at least thirty days before the day of the annual meeting, stating the hour at which the polls will close on that day. These ballots shall contain the nominations submitted by the nominating committee and also all additional nominations made in accordance with the terms of the preceding paragraph, in alphabetical order and without any designation to indicate the manner in which candidates have been nominated. Each ballot shall be returned to the Secretary inclosed in two sealed envelopes, the inner one to be blank and the outer to be indorsed with the member's signature. The President shall appoint two tellers, who shall canvass all ballots, and the result shall be announced at the annual meeting.

Of the candidates for any office, the one having the largest number of legal votes by letter-ballot shall be elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied; a majority of the votes cast being required to elect.

Vacancies occurring in any office may be filled by ballot at the first meeting after notice of the same has been sent to each member; a majority of the votes cast being necessary to elect.

Add at the end of Section 6 the following:

The Librarian shall receive an annual salary of $50.

Amend Section 10 by striking out the last sentence of the first paragraph and substituting therefor the following:

New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1, they shall be liable for only one half of the annual dues for the ensuing year, so as to read as follows:

10. Fees and Dues.—The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1, they shall be liable for only one-half of the annual dues for the ensuing year.

The Board of Government may deduct the cost of the Journal from the dues of members who receive said Journal from other sources.

If the annual dues prove insufficient to meet the expenses of the Society, it may levy assessments on its members and associates not exceeding four dollars per person in any one year.

Add a new section, to be numbered 15, as follows:

15. Sections.—The Board of Government may from time to time, at its discretion, establish sections for the consideration of special branches of engineering. Such sections shall in all cases be known as "The [name] Section of the Boston Society of Civil Engineers."

Each section shall consist of not less than ten members of the Society, with such other persons as shall be elected by the section as its members after approval of their applications by the Board of Government.

Section members, who are not members of the Society, shall be entitled to attend all meetings and excursions, to use the library, and to receive the publications of the Society.

Papers and discussions may be reported in accordance with the section by-laws, and shall be published in the same manner and subject to the same conditions as obtain with respect to papers read before the Society.

All sections shall be governed by the Constitution and By-laws of the Society, so far as applicable, but they shall be entitled to make additional by-laws for their own use and government; *provided, however,* that said additional by-laws be not inconsistent with the Constitution and By-laws of the Society, and that they be approved by the Board of Government.

The general government of each section shall be vested in an Executive Committee, consisting of the President of the Society, and the Chairman, Vice-Chairman, Clerk and three additional members of the section.

The officers of each section, who shall be elected by it annually, shall be a Chair-

man, a Vice-Chairman, a Clerk, and three additional members of the Executive Committee.

The fees and dues for members of sections who are not members of the Society shall be: Entrance fee, $5 and annual dues, $5, which shall be paid to the Secretary of the Society. The dues for the remainder of the first fiscal year after date of election shall be remitted to members of sections.

Members or associates of the Society may, without election, become members or associates of any sections, under such regulations as may be prescribed by the by-laws of the sections, without the payment of additional fees or dues.

Any member of a section becoming a member of the Society shall pay the difference between the entrance fees of the Society and the section, but shall pay no dues to the Society for the remainder of the fiscal year after his election.

The Chairman of Sections shall be entitled to seats in the Board of Government, but without votes.

Any section may be abolished by the Society by a two-thirds vote at any regular meeting, upon recommendation of the Board of Government, due notice of such recommendation having been sent with the notice of the meeting to each member of the Society, and to each member of the particular section who is not a member of the Society; and all members of the particular section shall be entitled to be heard at this meeting.

Resignations, forfeiture of membership or expulsion of members of sections shall be governed by the same conditions and methods of procedure as apply to members of the Society.

Renumber the present Section 15, making it Section 16.

Respectfully submitted,

FREEMAN C. COFFIN, *Chairman.*
HENRY MANLEY.
GEORGE A. KIMBALL.
FRANCIS W. DEAN.
OTIS F. CLAPP.
EDWARD F. MILLER.
SIDNEY HOSMER.
CHARLES W. SHERMAN.
LEONARD METCALF, *Secretary.*

Mr. Manley dissents from so much of the foregoing recommendation as relates to the Nomination and Election of Officers (Section 5).

On motion of Mr. L. F. Rice it was voted to receive the report, and under the ruling of the chair this included the minority report of Mr. Manley.

After a discussion on the advisability of adjourning this meeting to a special date it was finally voted, on motion of Mr. Hodgdon, to make the consideration of the proposed amendments to the By-laws the special business at the next regular meeting, and that the Board of Government call a special meeting, if it deem it advisable, for the consideration of any literary exercises which would have been presented at the regular meeting.

It was also voted, on motion of Mr. Hodgdon, to print in the notice of the November meeting any additional amendments to the By-laws which may be sent to the Secretary.

President Hollis then gave a very interesting description of the concrete-steel stadium for Harvard College now under construction on the Soldiers' Field.

Adjourned. S. E. TINKHAM, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, SEPTEMBER 4, 1903.—Called to order at 8.30 o'clock P.M. by Director Stetson G. Hindes.

The minutes of the last regular meeting were read and approved.

Mr. James T. Ludlow, mechanical engineer, addressed the members on

the subject of "Methods of Refrigeration," which he illustrated by a number of fine lantern slides. The paper was one of extreme interest and caused a long discussion, bearing directly upon the various means of modern refrigeration.

The Chairman expressed to the author of the paper the appreciation of the Technical Society, whereupon the meeting adjourned.

OTTO VON GELDERN, *Secretary*.

REGULAR MEETING, SAN FRANCISCO, OCTOBER 2, 1903.—Called to order at 8.30 o'clock P.M. by Past President Marsden Manson.

The reading of the minutes of the last regular meeting was dispensed with, the Secretary explaining that the Record Book had been left at his office by an oversight.

The Secretary read a memorial to the late August H. Schierholz, member of the Technical Society, during the reading of which the Society remained standing. This memorial was ordered to be sent to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for publication, and that a number of copies be struck off independently for distribution among his immediate relatives and friends.

Mr. Geo. W. Dickie read a paper entitled, "Is It not Time to Consider whether Patent Laws are any Longer Necessary to Progress in the Mechanical Arts?"

This paper caused considerable discussion, the discussion to be continued at the next meeting, for which Mr. John Richards has promised a similar contribution by the following letter, which was read:

"I beg to state that I will, at any future time, designated by yourself or the Executive Committee, present a paper on 'The Influence of Patent Inventions on the Social, Economic and Industrial Interests of Our Time.' As such a paper may in some respects present different views from those contained in Mr. Dickie's paper, it may be proper to explain that I cannot confine my remarks to progress in mechanical engineering, not knowing whether *discovery* alone is meant thereby; hence have chosen the wider and perhaps cumbrous title."

The Secretary was instructed to communicate with Mr. Richards and to place at his disposal the evening of the November meeting for the purpose of receiving and discussing the subject from his standpoint.

The Chairman referred to the prosperous financial condition of the Society, calling attention to the fact that a surplus had gradually accumulated in the treasury, showing an encouraging state of affairs, which, however, seemed not borne out by the general attendance at meetings, which had fallen off considerably.

Mr. Dickie offered the explanation that the attendance is dependent upon the papers presented for discussion and debate. With an adequate number of subjects the members would attend regularly. He realized the difficulty of preparing elaborate papers for such frequent meetings as once a month, and suggested that meetings be held but twice or three times a year; that such meetings last several days, and that during such semi-annual or tri-annual meetings more extensive preparations be made; that six or eight papers properly prepared for such occasions be read and discussed by large assemblies, from all parts of the State, and that in this way a new and more

active interest be aroused, that would be impossible to keep up where meetings are held from month to month.

Most members appeared to agree with Mr. Dickie, and manifested a strong desire that this new departure be tried. If the constitution call for monthly meetings, these might be held as heretofore for topical discussion and business transactions, but that the main effort of the Society should be made and concentrated upon two prominent gatherings per year, for which ample preparation should be made, and sufficient time given to those members who had important technical communications to present to the Society.

A motion was made by the Secretary that the Chair appoint a committee of three to study the conditions and outline a plan of future Society meetings on the basis suggested by Past President Dickie, that a limited number of meetings be held per year for the purpose of reading and discussing professional papers, and to make these meetings an inducement for well-attended and energetic gatherings; this committee to report at the next regular meeting. This motion was carried.

Chairman Manson appointed on this committee the following: Past President Geo. W. Dickie, President D. C. Henry and Secretary Otto von Geldern.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of St. Louis.

566TH MEETING, ST. LOUIS, OCTOBER 7, 1903.—Held at the Club rooms, 709 Pine Street, at 8.15 P.M., President Van Ornum in the chair.

Present, thirty-four members and seven visitors.

The minutes of the 565th meeting were read and approved.

The minutes of the 352d meeting of the Executive Committee were read.

The application for membership of Mr. L. V. Vella was read and referred to the Executive Committee.

The following gentlemen were, on ballot, unanimously elected to membership: F. C. Albrecht, Edward B. Day, J. V. Hanna and E. F. Wiederholdt.

The Secretary read a letter from the Engineering Association of the South, thanking the Club for the tender of the use of its Club rooms during the coming convention of the Engineering Association of the South in St. Louis.

A vote of thanks was given to Messrs. Robert Moore and S. E. Freeman for contributions to the library.

The paper of the evening, by Mr. A. P. Greensfelder, on "Some Proposed Improvements in St. Louis Terminal," was then read. The author confined his remarks to improvements along the lines of the Terminal Railroad Association of St. Louis. He gave interesting descriptions of the work being done by this company in providing increased facilities to adequately take care of the rapidly growing commerce of St. Louis. He showed what improvements were under way at all points of the system, and how they would help to relieve the present congestion due to inadequate facilities. The subway work, track changes, interlocking plant and power house for the Union Station were described with some detail, and showed that the

Terminal Association was expending large sums of money on its increased facilities. The paper was discussed by Messrs. Hermann, Van Ornum, Johnson and Humphry, after which the meeting adjourned.

H. J. Pfeifer, *Secretary.*

567th Meeting, St. Louis, Mo., October 21, 1903.—A regular meeting of the Engineers' Club of St. Louis was held at the Club rooms, 709 Pine Street, on Wednesday evening, at 8.15 p.m.; President Van Ornum in the chair. Thirty-one members and three visitors present.

The minutes of the 566th meeting were read and approved.

The minutes of the 353d meeting of the Executive Committee were read.

The applications for membership of Messrs. J. F. Hinckley and W. E. Rolfe were read and referred to the Executive Committee.

The chair announced that the American Society for the Advancement of Science would hold a convention in St. Louis in January, 1904, and that the committee in charge of the convention was desirous of having the Engineers' Club of St. Louis participate in entertaining the members of this Society. It was moved by Mr. Russell, seconded and carried, that the President appoint a committee of three to co-operate with other committees in the entertainment of the members of the American Society for the Advancement of Science. The President appointed Messrs. S. B. Russell, R. H. Fernald and A. P. Greensfelder to serve on the committee.

It was moved by Mr. Hermann, seconded and carried, that the recommendation of the Executive Committee relative to the participation of the Club in the World's Fair be adopted, and that the Executive Committee be empowered to make the necessary arrangements.

The paper of the evening, by Mr. W. M. Carr, chief chemist of the American steel foundries, at East St. Louis, Ill., on the "Heat Treatment of Steel," was then read. Mr. Carr's paper was illustrated by lantern slides, and showed the great care that is being taken in the modern steel foundries to turn out reliable material. He showed how the temperature to which the metal is subjected and its rate of cooling effects its durability and hardness. The paper was discussed by Messrs. Russell, Langsdorf, Phillips, Mitzger, Van Ornum, Wheeler, Kessler, Hermann, Freeman, Greensfelder and Hanna.

A vote of thanks was unanimously tendered Mr. Carr for his kindness in addressing the Club, after which the meeting adjourned to the lobby, where a light luncheon was served.

H. J. Pfeifer, *Secretary.*

Association of Engineering Societies.

Vol. XXXI. **November, 1903.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

568th Meeting, November 4, 1903.—The meeting was held at the Club rooms, 709 Pine Street, at 8.15 p.m.; President Van Ornum in the chair. Twenty-one members and three visitors were present.

The minutes of the 567th meeting were read and approved.

The minutes of the 354th and 355th meetings of the Executive Committee were read.

The following gentlemen, who were on ballot, were unanimously elected to membership: J. F. Hinckley, W. E. Rolfe and L. B. Vella. In accordance with the By-laws the Club then proceeded to elect a Nominating Committee, to nominate officers of the Club for the ensuing year.

The following were put in nomination as members of the Nominating Committee: A. H. Zeller, F. C. Bausch, Gerard Swope, A. S. Langsdorf, Wm. H. Bryan, Hans Toensfeldt and Edward Flad. Of these Messrs. Zeller, Flad, Langsdorf, Swope and Bryan were elected.

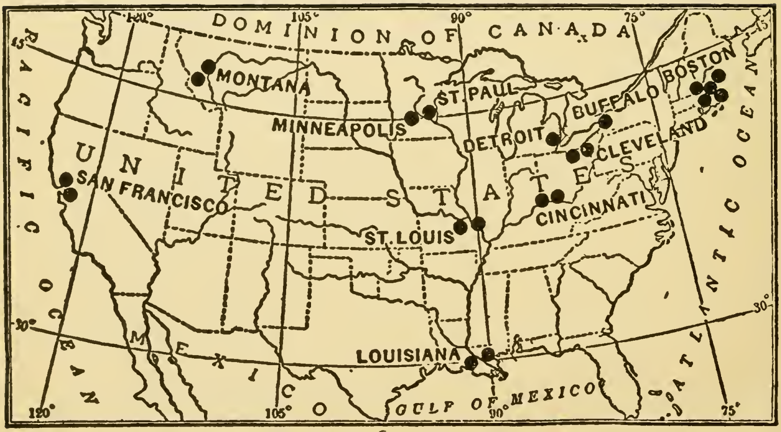
The President then read a letter from His Honor Rolla Wells, Mayor of the city of St. Louis, asking the Club to solicit subscriptions for an appropriate gift to the battleship "Missouri." It was moved and seconded that the chair appoint a committee of three to comply with the request of the Mayor.

The chair appointed on this committee Messrs. Layman, Pitzman and R. H. Phillips.

It was decided to have at the next meeting of the Club, as a special order of business, a discussion as to the advisability of discontinuing the awarding of the annual prize for the best paper read during the year.

The paper of the evening, by Prof. R. H. Fernald, on "Methods for Determining the Temperature of Gas Engine Exhaust," was then read. The author outlined a number of interesting experiments made by himself in the laboratory of the Columbia University in New York city. The paper was illustrated by a number of diagrams and other illustrations. The paper was afterwards discussed by Messrs. Hazzard, Freeman and Layman, after which the committee adjourned to the lobby, where a light luncheon was served.

Adjourned. H. J. Pfeifer, *Secretary.*


DOMINION OF CANADA
UNITED STATES
PACIFIC OCEAN
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MONTANA
ST. PAUL
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DETROIT
BUFFALO
BOSTON
CLEVELAND
CINCINNATI
SAN FRANCISCO
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

Vol. XXXI. **December, 1903.** No. 6.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., November 6, 1903.—Called to order at 8.30 p.m. by Past-President Manson.

In the absence of the Secretary, Mr. C. E. Grunsky was called upon to act in his stead.

The minutes of the last two regular meetings, September and October, were read and approved.

The committee appointed at the last regular meeting on the proposed amendment to the By-laws, relating to Stated Meetings and their most practical frequency, handed in a report, which was read as follows:

To the Technical Society of the Pacific Coast:

Your committee, appointed at the last regular meeting of October, to whom was referred the matter of the frequency of Society meetings for reading and discussing technical papers, has given this subject the fullest consideration, and begs to report as follows:

We believe that better results could be obtained if, instead of meeting regularly from month to month, only two general meetings for the year were held, one in the spring and one in the autumn.

The constitution of the Society does not specify how often meetings shall be held. This is regulated by Section 2, Article I, of the By-laws, which provides that the regular "Stated Meetings of the Society shall be held on the first Friday of each month."

It will not be difficult to amend this particular Section should the Society consider our recommendation worthy of approval, for the By-laws may be amended at any regular meeting by the vote of the majority of the members present, provided that at least seven votes be cast in favor of the amendments, and that notice of such proposed amendments shall have been presented in writing at the previous regular meeting.

The one main difficulty the Society has had to contend with—not only this, but all societies of a similar character—is to provide papers on technical subjects; while in the earlier history of an organization the enthusiasm may bring forth subject-matter for a long-continued season, experience has taught that the spirit of apathy is sure to follow, and the difficulty of obtaining

papers becomes more and more formidable. To ask for them is like asking for a special favor, and this must be all the more apparent if the stated meetings repeat themselves at frequent intervals. With a lack of papers follows a lack of interest and, in consequence, a lack of attendance, and the prospective author is all the more reluctant to address a meeting consisting of a few members on a subject that may involve considerable trouble, time and expense. It is reasonable to expect appreciation for an earnest and sincere effort, and it is but a natural result to see the work among our members in that direction fall off from year to year.

We propose to better these conditions by making each meeting of the Society an event, but in order to carry out a program of an extensive character successfully, the meetings should not be held more than twice during the course of the year; that is, meetings for reading and discussing prepared papers on technical subjects. This need not exclude monthly meetings for the transaction of business or for the informal discussion of any subject that may appear to be of immediate interest. But the formal meetings, convened for the improvement of members and the advancement of the technical professions, should be concentrated to not more than two systematically arranged meetings per year. For these occasions the papers should be prepared in the preceding six months and should have passed through the hands of the proper committee and approved for admission into a prearranged program.

These meetings should not be confined to one evening, but, announced as semi-annual gatherings of the Society, they should last for two days and nights. The program might include visits incorpore to points of interest and social meetings in the nature of public receptions or dinners; these are matters of detail that are easily arranged subsequently if we are finally agreed upon such a radical change as the one now proposed.

By making each meeting an event it will not be difficult to draw visitors from all parts of the State and from all the local members of the great American Societies, many of whom are members of the Technical Society of the Pacific Coast.

Now, then, in order to facilitate matters and to obtain the sense of our members on this proposed change, your committee begs to offer the following amendments to the By-laws:

Strike out Section 2, Article I, of the By-laws, which reads:

"Sec. 2. The regular Stated Meetings of the Society shall be held on the first Friday of each month, at the Hall of the Society, at 8 P.M."
and substitute therefor:

Sec. 2. The regular Stated Semi-annual Meetings of the Society shall be held on the first Friday and Saturday of the month of March and on the first Friday and Saturday of the month of September of each year, according to an arranged program provided by the Executive Committee of the Board of Directors, and for the purpose of reading and discussing technical papers, as well as for stimulating professional and social intercourse among members.

Amend Section 3, Article I, by placing before the present Section the following words:

Monthly stated meetings may be held on the first Friday of any month for the transaction of the ordinary business of the Society and for informal topical discussions.

And it is further amended to strike out all of Section 5, Article I, which would be in conflict with Section 2 as now amended.

We would recommend that this report be accepted as a written notice of the proposed amendments to the By-laws, that it be referred to the Board of Directors for its approval or for such modification as may be necessary to avoid conflict with any other section now existing, that the Board of Directors report back the proposed amendments ratified and approved at the regular December meeting, and that at that meeting they be submitted to the vote of the Society according to Aricle X of the By-laws.

We feel confident that changes on these lines will awaken an interest in the Society, which has lost the hold upon its members for no other reason than that it could not supply its frequent meetings with technical subjects properly prepared. Let it be known that hereafter each semi-annual meeting will be made a technical event in San Francisco, and we are sanguine that the Society will regain its former popularity and will become a factor in the consideration of technical affairs in the city of San Francisco and in the State of California. There is a want and a field of operation for a technical organization in this community, and how to make its influence best felt has been the object of the changes herein proposed.

Respectfully submitted,

Geo. W. Dickie,
D. C. Henny,
Otto von Geldern,
Committee.

On motion the recommendations made by the committee were adopted. The amendments are to be considered introduced and read, and are to be voted upon at the next regular meeting, in accordance with Article X of the By-laws, which provides that any proposed amendment shall have been presented in writing at any regular meeting, and that at the meeting following the reading such proposed amendment may be approved by the vote of the majority of the members present; at least seven votes must be cast in favor of such amendment.

The Secretary read a report presented by the committee instructed to write a fitting memorial to the late George F. Allardt, member Technical Society, which was ordered to be published in the Journal and spread in full upon the minutes.

The paper of the evening was read by Past-President John Richards, entitled "The Administration of Patent Laws." This was followed by a discussion in which Mr. Geo. W. Dickie was the principal speaker, who complimented Mr. Richards on the logical presentation of the subject and stated that he fully agreed with him in the position taken and in the line of the produced argument.

The following applications for membership were made: Joseph Jacobs, civil engineer, San Francisco; proposed by Chas. B. Wing, John H. Wallace and Otto von Geldern. Robert Hauxhurst, civil engineer, Hilo, Hawaii; referred to Chas. H. Kluegel, E. F. Haas, J. J. Hollister, Norman B. Livermore and Chas. D. Marx.

The applications were referred to the Board of Directors for approval, with instruction to proceed to ballot if found satisfactory.

Adjourned.

C. E. Grunsky, *Secretary pro tem.*

Boston Society of Civil Engineers.

Boston, November 18, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M.; Vice-President Frederick Brooks in the chair. Fifty-six members and visitors present.

The record of the last meeting was read and approved.

Mr. Frank T. Daniels was elected a member of the Society.

The chair announced the death of Frank P. Johnson, a member of the Society, which occurred on November 1, 1903. On montion, the President was requested to appoint a committee to prepare a memoir. The President has named the following as members of that committee, Bertram Brewer and Joseph R. Worcester.

The Board of Government submitted a report, giving the result of the informal ballot on the question of adopting a badge and on the expression of the preferences of members among the several designs submitted.

The meeting then took up the question of the adoption of a Society badge, and after a general discussion on the preference among the five designs, as shown by the informal letter-ballot, it was voted to adopt a Society badge.

The discussion was then continued upon the advisability of submitting to a formal letter-ballot the selection of a badge, but upon a vote being taken the Society declined to issue such a ballot.

The Society then voted to adopt as its badge the design here shown and substantially in accordance with the sample presented at the meeting.

On motion, the Board of Government was authorized to arrange for the manufacture and sale of the badges.

The amendments to the By-laws, as presented at the last meeting by the Committee on Revision, was then taken up. On motion of Professor Allen, it was voted to amend By-law 6, by adding at the end the words "The librarian shall receive an annual salary of $50." Fifty voted in favor and none against, and the amendment was adopted.

On motion of Mr. Howe, it was voted to amend By-law 10, so as to read:

Fees and Dues.—The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. New members shall not be liable for the annual dues for the year in which they are elected, and if elected after October 1st, they shall be liable for only one-half of the annual dues for the ensuing year.

The Board of Government may deduct the cost of the Journal from the dues of members who receive said Journal from other sources.

If the annual dues prove insufficient to meet the expenses of the Society, it may levy assessments on its members and associates not exceeding four dollars per person in any one year.

Forty-six voted in favor and six against, and the amendment was adopted.

It was then voted to proceed to the consideration of the proposed by-law, numbered 15, in the committee's report. It was also voted to take up the matter paragraph by paragraph.

After a prolonged discussion the several paragraphs were adopted in the following form:

Sections.—The Board of Government may from time to time, at its discretion, establish sections for the consideration of special branches of engineering. Such sections shall in all cases be known as "The [name] Section of the Boston Society of Civil Engineers."

Each section shall consist of not less than ten members of the Society, with such other persons as shall be elected by the section as its members after approval of their applications by the Board of Government.

A member of a section, who is not otherwise a member of the Society, shall be entitled to attend all meetings and excursions, to use the library and to receive the publications of the Society, to take part in the discussions of any papers on professional subjects or of any business affecting his particular section at any such meeting, but shall have no vote, except in his section.

Papers read before sections and discussions thereon may be reported in accordance with the section by-laws, and shall be published in the same manner and subject to the same conditions as obtain with respect to papers read before the Society.

All sections shall be governed by the Constitution and By-laws of the Society, so far as applicable, but they shall be entitled to make additional by-laws for their own use and government; *provided, however*, that said additional by-laws be not inconsistent with the Constitution and By-laws of the Society, and that they be approved by the Board of Government.

The officers of each section shall be a chairman, vice-chairman and clerk, who shall be elected by the members of the section annually.

The general government of each section shall be vested in an Executive Committee, consisting of the President of the Society, the officers of the section and three additional members of the section, who shall be elected annually.

The fees and dues for members of sections who are not members of the Society shall be: Entrance fee, $5; annual dues, $5; which shall be paid to the Secretary of the Society. The dues for the remainder of the first fiscal year after date of election shall be remitted to members of sections.

Members or associates of the Society may, without election, become members or associates of any section, under such regulations as may be prescribed by the by-laws of the sections, without the payment of additional fees or dues.

Any member of a section upon becoming a member of the Society shall pay the difference between the entrance fees of the Society and the section but shall pay no dues to the Society for the remainder of the fiscal year after his election.

The chairmen of sections shall be entitled to be present at the meetings of the Board of Government, but without votes.

Any section may be abolished by the Society by a two-thirds vote of all the members present at any regular meeting upon recommendation of the Board of Government due notice of such recommendation having been sent with the notice of the meeting to each member of the Society, and to each member of the section in question who is not a member of the Society; and all members of the section in question shall be entitled to be heard at this meeting.

Resignations, forfeiture of membership, or expulsion of members of sections shall be governed by the same conditions and methods of procedure as apply to members of the Society.

Under a ruling of the chair, that the amendments in their present form had not been presented at the previous meeting and therefore could not be adopted at this meeting, final action went over to the next meeting.

Messrs. E. W. Howe and J. H. Kinealy each proposed in writing amendments to By-law 5, in relation to the nomination and election of officers.

Mr. Hodgdon stated that in order to prevent any question in regard to By-law 15, of the report of the Committee on Revision of By-laws as

amended at this meeting, being in order for consideration at the next meeting, he would present the section in due form at this time.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, DECEMBER 8, 1903.—A special meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President Ira N. Hollis in the chair. One hundred and thirty members and visitors present.

Prof. L. J. Johnson read the paper of the evening, entitled "Prominent Features in the Design of the Steel-Concrete Work of the Harvard Stadium." The paper was illustrated with numerous lantern views.

Prof. Charles L. Norton, of the Massachusetts Institute of Technology, followed with a short paper, describing some experiments on the protection of steel in concrete from rust.

Prof. Gaetano Lanza gave the results of some tests made at the Institute of Technology on concrete-steel beams and columns, and showed by lantern views some of the specimens tested.

Prof. A. W. French, of the Worcester Polytechnic Institute, described some of the methods used in erecting the stadium, and Professor Norton, in answer to an inquiry, gave the results of some experiments on the rusting of steel embedded in concrete.

After passing a vote of thanks to Professors Norton and French, for their interesting contributions to the evening's discussion, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 16, 1903.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M.; Vice-President Frederick Brooks in the chair. Thirty-five members present.

The records of the last regular meeting and that of the special meeting of December 8th were read and approved.

After a short discussion, on motion of Mr. Hodgdon, the new by-law, marked Section 15, in the report of the Committee on Revision, as amended at the last meeting and printed in the notice of this meeting, was adopted, twenty-three voting in favor and five against its adoption.

It was also voted unanimously to renumber the present Section 15, making it Section 16.

Mr. Cheney, for the Committee on Amendments to Boston Building Laws, submitted the following report:

The Committee on Amendments to Boston Building Laws would recommend the following amendments to the present laws:

SECTION 19. Immediately before table of "*Deflection.—Modulus of Elasticity*" insert the following:

Shearing and bearing stresses on bolts whether wrought iron or steel shall be not higher than allowed by the above table for wrought iron. All connections in skeleton buildings of which the height exceeds twice the least horizontal dimension, all joints in steel trusses and girders and all connections of such trusses and girders to the sides of steel columns, shall be made by means of rivets.

SEC. 19. Amend paragraph beginning "Stresses for Steel," so that it will read:

Stresses for steel are those for "*Structural Steel,*" having an ultimate tensile strength of 55,000 to 65,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength, and a minimum elongation in 8 inches of 1,400,000 divided by the ultimate strength, per cent.

Sec. 19. Amend the figure for the extreme fiber stress in cast iron in tension by increasing from *2500 to 3000.*

Sec. 19. In headings under both "*Stonework*" and "*Brickwork,*" after the word "Stresses," insert the words "*in compression.*"

Sec. 19. After the portion devoted to brickwork, insert the following:

Concrete.

When the structural use of concrete is proposed, a specification, stating the quality and proportion of materials, and the method of mixing thereof, shall be submitted to the Building Commissioner, who may issue a permit at his discretion and under such further conditions as he sees fit to impose.

In first-class Portland cement concrete containing one part cement, to not exceeding nine parts properly graded stone and sand, except in piers or columns of which the height exceeds six times the least dimension, the compressive stress shall not exceed thirty tons per square foot.

In piers and columns of first-class Portland cement concrete, containing one part cement to not exceeding seven parts properly graded stone and sand, where the height of pier or column is more than six times and does not exceed twelve times its least dimension, the compressive stress shall not exceed twenty-five tons per square foot.

In steel-concrete beams or slabs subjected to bending stresses, the entire tensile stress shall be carried by the steel, which shall not be strained above the limits allowed for this material. First-class Portland cement concrete in such beams or slabs, composed of one part cement to not exceeding seven parts of properly graded stone and sand, may be strained in compression not exceeding 500 pounds per square inch. In case one part of cement to not exceeding four parts of properly graded aggregate is used, this stress may be increased to not exceeding 600 pounds per square inch. Concrete shall not be strained in shear more than 50 pounds per square inch.

Section 23. After "iron," where it first occurs, omit the words, "*or steel,*" and insert "*steel or concrete-steel,*" and after "masonry arches," insert "*or concrete-steel slabs.*"

Sec. 27. After "covers," in third line from end, insert "*or with first-class Portland cement concrete containing one part of cement to not exceeding nine parts of properly graded stone and sand, the concrete to be filled in around the pile heads upon the intervening earth.*"

Sec. 30. In the third line, after "nineteen," insert "*or Portland cement concrete as provided in Section 27.*"

Sec. 30. Between lines 15 and 16, after "foundations of brick," insert "*or concrete.*"

Sec. 55 to be amended to read as follows: All new or renewed floors shall be so constructed as to carry safely the weight to which the proposed use of the building will subject them, and every permit granted shall state for what purpose the building is designed to be used; but the least capacity per superficial square foot, exclusive of materials, shall be:

For floors of dwellings and for apartment floors of apartment and public hotels, fifty pounds.

For office floors and for public rooms of apartment and public hotels, one hundred pounds.

For floors of retail stores, and public buildings, except schoolhouses, one hundred and twenty-five pounds.

For floors of schoolhouses, other than floors of assembly rooms, eighty pounds, and for floors of assembly rooms, one hundred and twenty-five pounds.

For floors of drill rooms, dance halls and riding schools, two hundred pounds.

For floors of warehouses and mercantile buildings, at least two hundred and fifty pounds.

The loads for floors not included in this classification shall be determined by the Commissioners, subject to appeal, as provided by law.

The full floor load specified in this section shall be included in proportioning all parts of buildings designed for dwellings, hotels, schoolhouses, warehouses, or for heavy mercantile and manufacturing purposes. In other buildings, however, certain reductions may be allowed, as follows: In girders carrying more than 100 square feet of floor, the live load may be reduced by 10 per cent. In columns, piers, walls, and other parts carrying two floors, a reduction of 15 per cent. of the total live load may be made; where three floors are carried, the total live load may be reduced by 20 per cent.; four floors, 25 per cent.; five floors, 30 per cent.; six floors, 35 per cent.; seven floors, 40 per cent.; eight floors, 45 per cent.; nine or more floors, 50 per cent.

Your committee would state that they have had the co-operation of the Committee

on Building Laws of the Boston Society of Architects and the Building Commissioner of the city of Boston, in the framing of the proposed amendments, and also their concurrence in the same.

Respectfully submitted,

JOHN E. CHENEY,
JOSEPH R. WORCESTER,
HENRY A. PHILLIPS,
Committee.

After a discussion, it was voted, on motion of Mr. Adams, that it is the sense of this meeting that the amendments to the Boston Building Laws proposed by the committee should be adopted, and that a copy of the report be presented to the Mayor of Boston with the vote of this meeting.

It was also voted to print the report in the notice of the next meeting, accompanied by the statement that it would come up for the Society's indorsement at that meeting, in accordance with Article V of the Constitution.

In the absence of any member of the committee appointed to prepare a memoir of our late associate, Alphonse Fteley, the Secretary read the memorial which the committee had prepared. It was voted to print the memoir in the JOURNAL.

Mr. Coffin voted to strike out Section 5 of the By-laws and substitute therefor the new by-law, Section 5, as submitted by the Committee on Revision at the October meeting. A long and earnest discussion followed, and at its conclusion the motion was lost, twelve voting in favor and eleven against the amendment, a two-thirds vote being required to amend a by-law.

Adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of Minneapolis.

169TH MEETING, MINNEAPOLIS, MINN., NOVEMBER 16, 1903.—The meeting was called to order by President Avery, in the County Commissioners' Room, Court House. About sixty members and friends were present. The following names were proposed for membership: F. D. Brown, T. S. Layman, H. A. Rogers, C. P. Howe, C. L. Dean, J. N. Pariseau, E. T. Hare, Jas. T. Keely, E. W. Ashenden, E. H. Scofield, J. H. Marten, Jr., A. N. Lundquist and Eug. Spence.

Mr. Avery announced the death of Mr. W. D. Van Duzee, an honorary member of the Club.

The following committee was appointed to draft suitable resolutions: Messrs. Redfield, Hoag and Sublette.

The program of the evening was then taken up. Mr. Francis Henry delivered a paper on "Changing the Course of Bassett's Creek through the Lakes and Minnehaha Falls." Discussion followed by Messrs. Cooley, Ilstrup, Sublette, Hoag, Loring, Fanning and Nutter. It was the general opinion of all speakers that, while the scheme appeared to be quite feasible, there were a great many difficulties to be taken into account, and that a very careful consideration should be given the subject before action was taken.

The hour being late, the remainder of the program, a paper also by Mr. Henry, on "Rice Irrigation and Culture in Texas and Louisiana," was postponed.

J. B. GILMAN, *Secretary.*

170TH MEETING, MINNEAPOLIS, MINN., DECEMBER 5, 1903.—A special meeting of the Club was held for the purpose of visiting the plant of the Minnesota Sugar Company. About one hundred members and friends availed themselves of the opportunity, assembling at Voegli's drug store, proceeding by car to St. Louis Park, where the plant is situated. The party was received by the President of the Company and his associates, and was shown through the works. The various processes of manufacture and purification by which granulated sugar is obtained from the beet were explained and shown, proving of great interest to those present.

J. B. GILMAN, *Secretary.*

Engineers' Club of St. Louis.

570TH MEETING, ST. LOUIS, MO., DECEMBER 2, 1903.—The meeting was held at the Club Rooms, 709 Pine Street, at 8.15 P.M.; President Van Ornum in the chair. Present thirty-two members and no visitors.

The first order of business was the nomination of additional candidates for office. None were made.

It was then moved, seconded and carried that nominations be closed.

In accordance with Article V, Section 1, of the Constitution, this was the annual meeting, and reports were read by the following officers and committees of the Club: Executive Committee (written by the President), Secretary, Treasurer, Librarian, Members of Board of Managers of Association of Engineering Societies, Members of Governing Board of Associated Technical Clubs, Committee on Smoke Abatement, Entertainment Committee (oral by the chairman of committee), Program Committtee.

All of these reports were ordered filed except that of the Treasurer, which was referred to the Executive Committee for auditing.

The Committee on Affiliation of Engineering Societies made a partial report through Mr. A. L. Johnson, chairman.

The Committee on Exposition Affairs and the Committee on Resolutions on the death of Professor Johnson were not ready to report.

Mr. Wm. H. Bryan announced the death of Mr. Geo. W. Fisher, a charter member of the Club.

The chair reported that in accordance with the request of the Hon. Rolla Wells, Mayor of St. Louis, the Engineers' Club membership and friends had contributed $124.90 to help defray the expenses of a suitable gift to the battleship "Missouri."

Mr. R. H. Phillips extended an invitation to the Club to visit the World's Fair Grounds at some time in the near future.

There being no further business the meeting adjourned.

H. J. PFEIFER, *Secretary.*